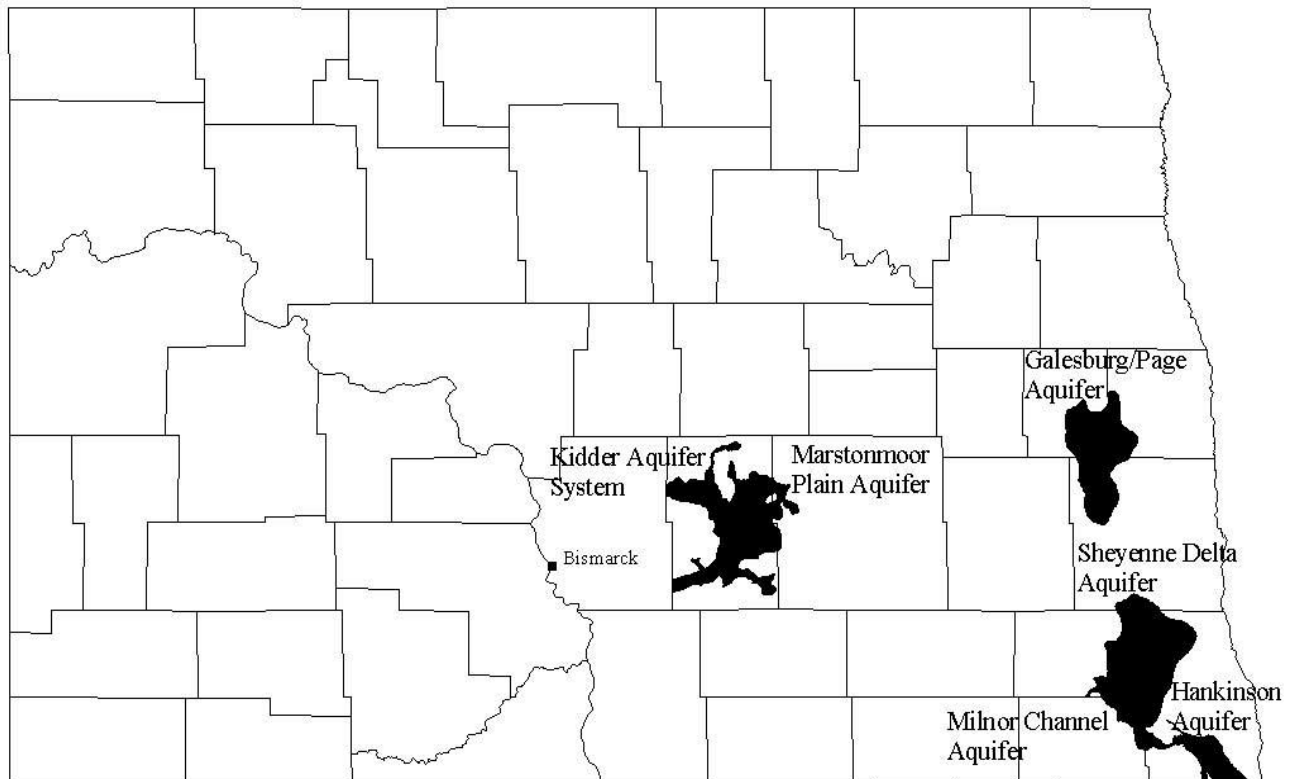


North Dakota Groundwater Monitoring Program 1999 Report



North Dakota Department of Health
Division of Water Quality

North Dakota Groundwater Monitoring Program

1999 Report

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ABSTRACT

To determine the degree to which agricultural chemical contamination of groundwater is occurring in North Dakota, an aquifer monitoring program was developed by the North Dakota Department of Health (NDDoH), Division of Water Quality. In 1999, monitoring was conducted in five aquifers. The Galesburg/Page, Hankinson, Milnor Channel and Sheyenne Delta aquifers were initially sampled as part of the ambient groundwater monitoring program in 1994. Added to the monitoring schedule was the Kidder aquifer system, which now includes the area formerly designated the Kidder County aquifer complex, the portion of the Marstonmoor Plain aquifer (also sampled in 1994) that lies in Kidder County and the Tappen aquifer (sampled in 1996). Because the portion of the Marstonmoor Plain aquifer in Stutsman County still bears that name, these aquifers will be referred to as the Kidder/Marstonmoor Plain aquifer for the purposes of this report.

All five aquifers consist primarily of sand and/or gravel and have fairly shallow water tables; several increasingly are being used for irrigation. A total of 290 wells were sampled for general anion and cation chemistry, nitrate and nitrite, and 60 selected pesticides or degradation products. Forty-three wells, about 15 percent, contained detectable concentrations of pesticides in the initial samples (included in the 43 wells is one well that *did not* have a pesticide detection the first time it was sampled; however, for quality control purposes, the well was resampled and a pesticide was detected in the follow-up sample). Follow-up samples were collected from 33 of the wells. Twenty-seven wells with initial pesticide detections did not exhibit pesticide detections in follow-up samples. Picloram was detected in eight wells in both initial and follow-up samples. Also confirmed in either follow-up or duplicate samples were bentazon, dicamba, malathion and trifluralin. The pesticide compounds detected by laboratory analysis were atrazine, bentazon, bromoxynil, carbaryl, cyanazine, 2,4-D, DDT, dicamba, diclofop methyl, dichlorprop, endosulfan I, endosulfan sulfate, endrin, endrin ketone, malathion, pentachlorophenol, picloram, simazine, 2,4,5-T and trifluralin. Most concentrations detected were far below their respective maximum contaminant level or health advisory level. The highest concentration of a detected pesticide, with respect to a health-based standard, was of cyanazine at 71 percent of its health advisory level. Neither cyanazine nor any other pesticides were detected in that particular well when it was resampled. Pesticides were detected in all five aquifers.

Nitrate plus nitrite as nitrogen (N) was detected above 0.05 milligrams per liter in 59 wells, or 20 percent of the wells sampled. Concentrations in five wells, 1.7 percent, exceeded the maximum contaminant level of 10 milligrams per liter (N). Based upon sampling site inventories, many of the nitrate detections were associated with shallow well depth, shorter distance from the top of the well to the top of the screened interval, and shorter distance from the water table to the top of the screen. Many of the pesticide and nitrate detections are believed to be associated with point sources of contamination.

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INTRODUCTION AND PURPOSE

The maintenance of a baseline description of groundwater quality is an essential element of a statewide comprehensive groundwater protection program. In recent years, concern for the quality of our environment and drinking water has increased as we learn that many states in the country have experienced groundwater contamination from a variety of point and nonpoint sources of pollution. Typically in North Dakota, available groundwater resources underlie agricultural areas; however, limited data exists to evaluate whether agricultural chemicals have impacted groundwater quality of the state on a broad scale. The goal of this project is to provide data relating to the overall quality of North Dakota's groundwater resources, with an emphasis on agricultural chemicals. Since 1992, several aquifers have been monitored each year of the project. Aquifers are resampled every five years in an effort to determine groundwater quality trends. Monitoring is conducted through the use of existing domestic wells, monitoring wells, livestock wells, public supply wells and irrigation wells that meet construction standards and sampling requirements described later in this report.

Monitoring conducted in 1996 marked the completion of the first-round monitoring for 45 of the highest priority glacial drift aquifers in North Dakota. In 1999, the Galesburg/Page, Hankinson, Milnor Channel and Sheyenne Delta aquifers were sampled for the second time since the 1992 initiation of the monitoring program. The Kidder aquifer system also was added to the sampling schedule in 1999 (Figure 1). This aquifer now includes the Kidder County portion of the Marstonmoor Plain aquifer (also sampled in 1994) and the Tappen aquifer (sampled in 1996). The portion of the Marstonmoor Plain aquifer in Stutsman County is still called by that name; for the purposes of this report, these aquifers will be collectively referred to as the Kidder/Marstonmoor Plain aquifer. These five aquifers are composed primarily of sand and/or gravel and have shallow water tables ranging from just below the ground surface to approximately 50 feet below grade. Several increasingly are being used for irrigation. Wells included in the study were sampled primarily during April through October 1999. Results from the monitoring will provide useful information about the overall quality of groundwater in the state.

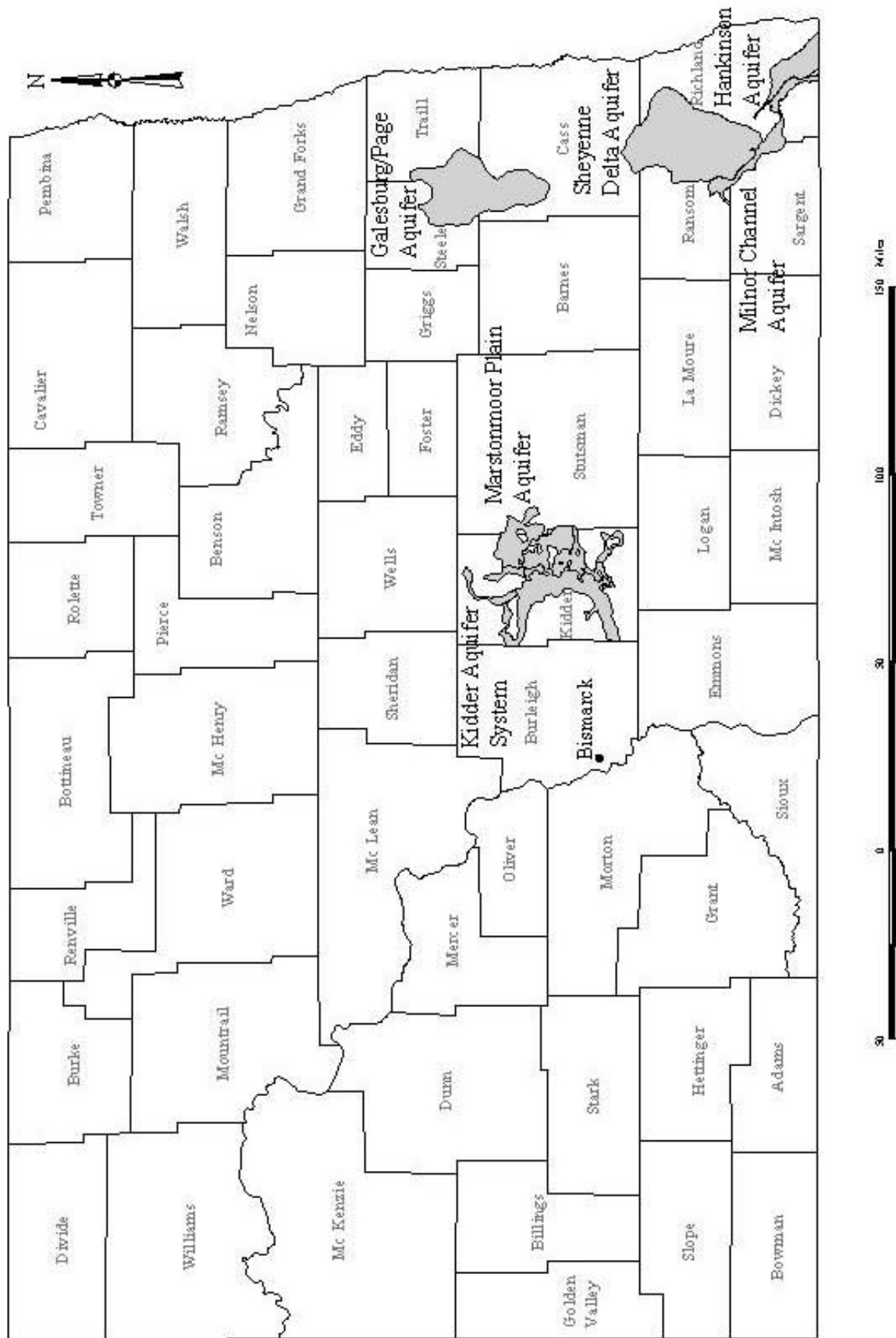


FIGURE 1. Locations of aquifers sampled in 1999 for the North Dakota Groundwater Monitoring Program

SUMMARY OF PREVIOUS INVESTIGATIONS

In recent years, several studies have been initiated to determine the presence and extent of pesticides in groundwater. The United States Environmental Protection Agency (EPA) (1990; 1992) conducted the National Pesticide Survey between 1988 and 1990 to determine the frequency and concentration of pesticides and nitrates in private and public drinking water wells. The survey investigated the association of pesticide detections with various factors such as pesticide use and groundwater vulnerability. For the survey, EPA sampled 566 community water system and 783 rural domestic drinking water wells throughout the nation for the presence of 126 pesticides and degradates, as well as nitrate. Of the analytes, 17 were detected in the survey, with five detected at levels above their respective Maximum Contaminant Level (MCL) or Health Advisory Level (HAL). Based on its findings, EPA estimated that approximately 9,850 (10 percent) community water system and 446,000 (4 percent) rural domestic wells in the United States contained concentrations of at least one pesticide above the minimum reporting level.

Glatt (1985) conducted a study of selected private and public wells to determine the presence of picloram in groundwater in Rolette County, N.D. Of the 126 water samples collected, picloram was found in 11 samples, ranging from less than 0.02 to 0.85 micrograms per liter ($\mu\text{g/l}$). All positive sites were retested, with picloram concentrations confirmed in four wells, ranging from 0.05 to 3.56 $\mu\text{g/l}$.

In 1986, Glatt sampled 92 municipal drinking water supply systems, with at least one municipal system sampled in 52 of the 53 counties in North Dakota. Water samples were analyzed for one or more of the following agricultural pesticides: aldicarb, fenvalerate, picloram, methyl parathion and 2,4-D. At least one of the five agricultural chemicals was detected in 10 of the water systems. Picloram, with concentrations ranging from 0.08 to 1.46 $\mu\text{g/l}$, was the pesticide detected in seven of the 10 positive sample locations. Three separate municipal drinking water systems had possible detections of ethyl parathion (less than 0.02 $\mu\text{g/l}$), methyl parathion (less than 0.04 $\mu\text{g/l}$), and trifluralin (less than 0.03 $\mu\text{g/l}$), respectively.

Murphy and Greene (1992) investigated the presence of picloram and 2,4-D on four tracts of land owned by the United States Bureau of Land Management in the Denbigh Sand Hills of McHenry County, N.D. A total of 68 groundwater samples and 33 sediment samples were collected. The

concentrations of picloram detected in groundwater ranged from 0.07 to 107 $\mu\text{g/l}$, and from 10 to 160 $\mu\text{g/l}$ in the sediment. Concentrations of 2,4-D in groundwater ranged from 0.09 to 2.19 $\mu\text{g/l}$, and up to 20 $\mu\text{g/l}$ in sediment samples.

Montgomery et al. (1988) collected baseline information from the Oakes aquifer for the purpose of assessing the environmental impact involving the Garrison Diversion Irrigation Project transfer of Missouri River water to the James River. A 31-square-kilometer test site was developed by the United States Bureau of Reclamation, with the installation of 98 observation wells on a 0.8-kilometer grid, four large drainage lysimeters, and 70 kilometers of slotted, plastic drain pipe. A total of 229 water samples were collected from the observation wells, lysimeters and manholes constructed in the drains for the period 1985 through 1987. Samples were analyzed for the presence of four commonly used herbicides: alachlor, metolachlor, simazine and atrazine. Concentrations of alachlor were detected in six of the 229 samples, ranging from a trace (0.2 $\mu\text{g/l}$) to 1.2 $\mu\text{g/l}$. Three of the detections were from samples of the same well collected during three different sampling episodes. The other three detections were from two lysimeters and a drain manhole. No detections of the other three herbicides were confirmed in any of the samples.

In a statewide study of 346 community and non-transient, non-community public water systems, Abel (1992) surveyed for the presence of certain regulated and non-regulated Volatile Organic Compounds (VOCs). In addition, those systems deriving their water supply from groundwater were tested for 14 herbicides and six insecticides, selected on the basis of their use in North Dakota and their mobility and persistence in soil. Two pesticides, alachlor (0.55 $\mu\text{g/l}$) and picloram (1.99 $\mu\text{g/l}$), were detected, representing less than 1 percent of the systems in the study.

Forty-eight high priority glacial drift aquifers were monitored during the first five-year round of sampling for the North Dakota Department of Health (NDDoH), Division of Water Quality, North Dakota Groundwater Monitoring Program, which began in 1992. Results of each year's monitoring are described in annual groundwater monitoring reports (Radig and Bartelson, 1992, 1993, 1994 and 1995; and Bartelson and Gunnerson, 1996). These results are summarized in the North Dakota Groundwater Monitoring Program 1992 to 1996 Summary Report (Bartelson and Gunnerson, 2000). The annual monitoring reports should be consulted for more detailed information about specific aquifers.

Groundwater samples were collected from 756 wells during the first five years of the NDDoH Groundwater Monitoring Program. Samples from 62 wells, or 8 percent of the wells sampled, contained detectable concentrations of one or more pesticides. One-half of all detections occurred in two aquifers: Elk Valley and Sheyenne Delta. Twenty-one pesticide species were detected during the monitoring period; picloram was the pesticide detected most often, accounting for 39 of 83 detections. One pesticide, dinoseb, was detected in one well at a concentration above its MCL; it was not detected upon resampling the well. Samples from 295 wells, 39 percent, had nitrate plus nitrite (N) detections greater than or equal to 0.05 mg/l. More than one-half of all nitrate detections occurred at concentrations less than 1.0 mg/l. Five percent (38 wells) had nitrate concentrations greater than or equal to the MCL of 10.0 mg/l (N). Most pesticide and nitrate detections are believed to be associated with point sources of contamination.

During the 1997 sampling season, Bartelson and Gunnerson began the second five-year round of monitoring by resampling the aquifers initially sampled in 1992, the first year of the program -- the Oakes, Warwick and Icelandic aquifers. Two additional aquifers, Spring Creek and Streeter, also were sampled for the first time in 1997. Nine pesticide species were detected in samples from seven wells, about 4 percent, of the 179 wells sampled. Most concentrations were at levels far below any health-based standard. However, two of the detected pesticides, MCPA and pentachlorophenol, were above their respective HAL and MCL. Follow-up samples were collected from all seven wells; four of the wells with initial detections did not have pesticides detected in follow-up samples. Nitrate plus nitrite was detected in 57 wells, or 32 percent of the wells sampled. Concentrations in 13 wells, 7 percent, exceeded the MCL of 10 mg/l (N). A majority of the pesticide and nitrate detections are believed to be associated with point sources of contamination.

During the 1998 sampling season, Bartelson and Goven resampled the aquifers initially sampled in 1993: Denbigh, Elk Valley, Fordville, Inkster, Lake Souris and Shell Valley. The Karlsruhe, McVille, New Rockford, Strawberry Lake and Turtle Lake aquifers also were added to the sampling schedule. Seven pesticide species were detected in 19 wells, or 9 percent, of the 214 wells sampled in the 11 aquifers, all at concentrations below their respective MCL or HAL. Picloram was the only pesticide confirmed in follow-up samples. Fifty-one wells, 24 percent, had nitrate detected. Samples from 15 wells, 7 percent, were greater than the MCL of 10 mg/l (N).

Schuh et al. (1995) investigated the relationship between groundwater recharge and agricultural chemical movement. The investigation was conducted in a crop production plot at the Carrington Research Extension Center in Foster County, N.D., to assess the impact of pesticides on the Carrington aquifer, a buried sand and gravel deposit existing primarily under confined conditions. Monitoring wells were installed around the plot and nested at three depths: in the vadose zone, in the saturated overlying till and at the top of the aquifer. Low concentrations of pesticides were detected at all sampling depths; however, detections were generally sporadic and spatially and temporally discontinuous. Most pesticide detections were below levels of toxicological concern, and there was no evidence of pesticide accumulation in the saturated till or the Carrington aquifer. In general, the investigators concluded that pesticide detections corresponded to periods of recharge and were depression-focused.

STUDY DESIGN

The North Dakota Groundwater Monitoring Program is designed to provide a consistent approach to water quality determinations by defining target populations and criteria for sample site selection.

Target Population

The target population, or set of environmental units, that this study addresses includes all groundwater wells capable of producing significant amounts of water. Statistically, it is impossible to use a whole aquifer as the target population for a monitoring study because it is impossible to take an "overall" sample of an aquifer. Groundwater samples must be collected from wells or springs; therefore, the population that most closely correlates to the overall quality of an aquifer is the set of all wells completed in an aquifer.

Criteria for Acceptable Sampling Points

Because of the necessity to produce reliable and representative data, some limitations were put on the target population. A number of criteria were used to determine whether a well was acceptable for use as a sampling point. These criteria were used to ensure that the sample would

be representative of groundwater in that area and that there was data available to determine relationships between well and/or site characteristics and groundwater quality. The criteria used include:

- ▶ Wells capable of being pumped dry by small capacity pumps (one to two gallons per minute), or that can be bailed dry were not included in the target population;
- ▶ The well must have a drilling and well completion log available to document the construction of the well and the geology of the aquifer material at the site;
- ▶ The well must be accessible and open for bailing or have an operable pump installed;
- ▶ The well must be capable of being sampled before any treatment of the water occurs; and,
- ▶ Permission of the owner or other responsible person must be received before the well may be sampled.

Sampling Grid

In an ideal monitoring program, every population unit in the target population would be sampled. However, due to the practical constraints of time, budget and personnel, not all wells could be sampled. A sampling grid based on township, range and section boundaries was used. The size of a grid unit was one section, normally one square mile. Sections that only partially overlie an aquifer were included with that aquifer if they contained acceptable sampling points.

Using Gilbert's (1987) method of determining "hot spots," a circular area of non-point source contamination with a radius of 0.56 miles has a 90 percent chance of being detected by a one-mile-square uniform sampling grid. Because the sampling grid was not precisely uniform (the sample point could be anywhere within the grid block), the size of this 90-percent-confidence detection circle would be slightly more or less than 0.56 miles.

Selection of Sampling Points

A maximum of one well from each section was sampled for this survey. The shallowest well that met the sampling criteria and was nearest the center of the section was selected for sampling. Based upon previous sampling results (only one questionable pesticide detection), wells with a depth greater than 100 feet generally were not sampled. Whenever possible, an alternative well was chosen for sampling in case the first selection was not capable of being sampled.

The only bias built into the monitoring program was toward shallower wells rather than deeper wells and toward newer wells rather than older wells, because drilling logs were not required prior to enactment of the North Dakota Water Well Construction Code in 1971. The other characteristics of the sample site, such as water use and nearby land use, were strictly random.

Criteria for Selecting Aquifers

Radig (1997) developed a system of prioritizing aquifers that may have the highest potential for groundwater pollution. The Geographic Targeting System for identifying those aquifers is based on the DRASTIC groundwater vulnerability assessment model (Aller et al., 1987), as well as components for agricultural chemical usage and risk. The acronym DRASTIC stands for **d**epth to groundwater, **r**echarge, **a**quifer media, **s**oil media, **t**opography, **i**mpact of the vadose zone and **c**onductivity. These parameters are considered important in the transport of contaminants to groundwater. The Geographic Targeting System does not evaluate small areas within aquifers to determine recharge zones or critical areas, but rather evaluates aquifers as whole units to determine their relative average pollution potential. In some cases, large aquifers were subdivided into hydrogeologic settings with similar characteristics to aid in the evaluation process. Aquifers are chosen for groundwater monitoring based on a combination of their pollution potential and the volume of groundwater withdrawn from the aquifer for beneficial uses, such as drinking water supplies or irrigation. Aquifers are periodically re-evaluated for factors such as permitted water usage; therefore, an aquifer's ranking in the targeting system may move up or down accordingly.

Temporal Variability

All wells from which there was a pesticide detection in the initial sample are normally resampled at least once for confirmation purposes. Wells with sample analyses that exhibit a laboratory chromatographic peak below minimum detection limits, but that resembles a peak caused by pesticides, also will be resampled.

LOCATION NUMBERING SYSTEM

The wells and other data collection points mentioned in this report are numbered according to a system based upon the location in the public land classification of the U.S. Bureau of Land Management. The system is illustrated in Figure 2. The first numeral in the illustration denotes the township north of a base line, the second numeral denotes the range west of the fifth principal meridian, and the third numeral denotes the section in which the well is located. The letters A, B, C and D designate the northeast, northwest, southwest and southeast quarter section, quarter-quarter section and quarter-quarter-quarter section (10-acre tract), respectively. For example, well 161-55-15DAB is in the $NW^{1/4}NE^{1/4}SE^{1/4}$ of section 15, T. 161 N., R. 55 W. Consecutive end digits are added if more than one well or data collection point is within a given tract. Site identification numbers used for this study are the township, range, section and quarter digits combined without any dashes.

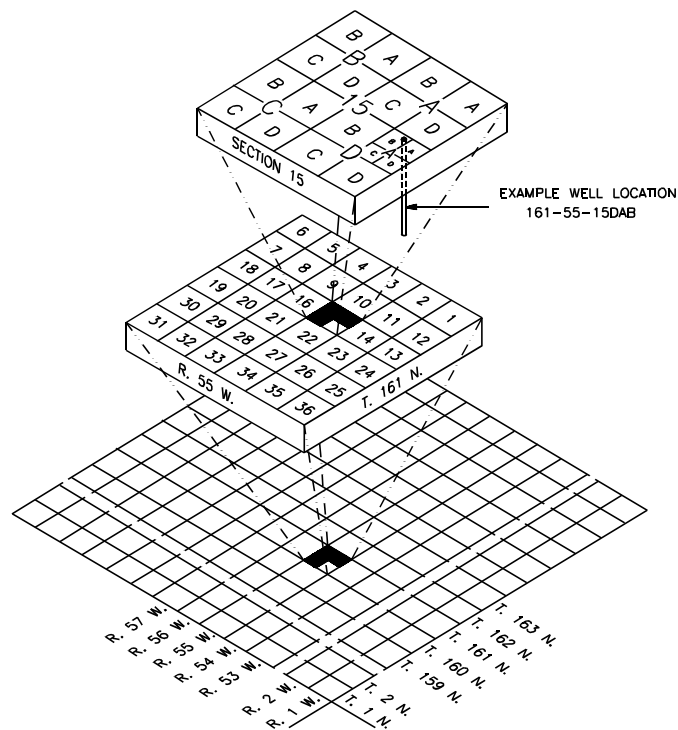


FIGURE 2. System of numbering wells, test holes and springs

QUALITY ASSURANCE / QUALITY CONTROL METHODS

The objective of a groundwater monitoring program is to produce data that is valid, accurate, complete, representative of the medium being sampled and comparable with other data. In view of this objective, a set of Standard Operating Procedures was developed and followed to encompass every aspect of groundwater monitoring, including sample collection, handling, preservation, field monitoring and uniform standards for the analysis and reporting of chemical data. Included in these procedures are certain methods for providing Quality Assurance/Quality Control (QA/QC). The Standard Operating Procedures used for this project include

- Locating the well site and collecting latitude/longitude data;
- Surveying well owners and filling out the field inventory form;
- Measuring water levels;
- Measuring temperature, pH and electrical conductivity;

- Well purging;
- The use and maintenance of sampling mechanisms; and
- Collecting and preserving groundwater samples.

Field sampling personnel were required to be familiar with these procedures and to have appropriate instruction manuals available for reference in the field. The project leader also served as the quality assurance representative, providing quality assurance oversight for the project.

A number of quality control checks were used in the field, including equipment calibration; collecting field duplicate samples to establish sampling and laboratory precision; collecting blank samples to assure noninterference with preservatives, sampling equipment or sample containers; and the use of standard solutions, reagents and lab-packaged vials of preservatives. A field duplicate sample and a field blank sample were collected with approximately one out of every 10 water chemistry samples collected. A notation was made in the site inventory form that the sample was a duplicate or a blank. The laboratory was not informed which samples were duplicates or blanks.

All equipment was inspected prior to departure for the field. Conductivity and pH meters were calibrated according to the manufacturer's specifications using standard solutions. Meters were calibrated daily and during sampling activities when necessary. Teflon® bailers and peristaltic pump tubing were used to prevent adsorption of pesticides on the sampler material and to facilitate effective cleanup.

All wells were purged prior to sampling to ensure that groundwater samples were representative of the aquifer. Purging the well removes stagnant groundwater in the well casing that may possess chemical and physical characteristics not representative of the aquifer water quality. Monitoring wells were purged by removing a minimum of three well volumes of water, and until stabilized readings of electrical conductivity, pH and temperature were obtained. Water pumps in wells for domestic, livestock and irrigation uses were allowed to run a minimum of five minutes prior to sample collection to increase the likelihood of collecting a representative sample.

To minimize cross-contamination of samples, the bailers and other equipment were decontaminated after sampling each well. Because the focus of this study was on pesticides (organics), decontamination procedures were followed that were appropriate for these parameters. The equipment was first washed withalconox, a non-phosphate detergent, then rinsed with deionized water. This was followed by an acetone rinse and then a hexane rinse. Disposable latex lab gloves were worn throughout sampling and decontamination processes to prevent contaminants from the skin from coming into contact with the sample and to protect the skin from the acetone and hexane rinses. Water level measurement tapes were rinsed with deionized water between measuring events. The gloves and the nylon cord used on the bailers were discarded and replaced after each well was sampled. Sample bottles were double-rinsed with sample medium, or, for blank samples, with deionized water. All samples were appropriately preserved, packed in ice and transported to the laboratory as necessary to comply with appropriate analytical holding times.

Prescribed field procedures, site inventory forms (Appendix A) and labels were used to ensure the orderly and consistent handling of all data collected. At the time of sample collection, field data and associated descriptive information were recorded on the site inventory form. This form includes information about the site location, well or location ID number, sampler(s), date and time of sample collection, method of sample collection, sampling equipment used and well-purging data. Immediately prior to collecting the sample, the sample container was labeled with the well or location ID number, date, time and name or initials of sampler(s). Field data recorded in the laboratory report was checked against site inventory forms for accuracy.

All samples were analyzed by the North Dakota Department of Health, Division of Chemistry (NDDoH, DC), utilizing EPA-approved analytical methods. Sample custody procedures, analytical methods used in the analysis of samples, and calibration procedures for the NDDoH-DC laboratory are included in the NDDoH, DC Quality Assurance Program Plan (1997).

HYDROGEOLOGIC DESCRIPTIONS OF THE AQUIFERS

Galesburg/Page Aquifer

According to Downey and Armstrong (1977), the Galesburg aquifer is located in portions of Steele and Traill Counties and includes deposits in Cass County previously assigned to the Page aquifer by Klausing (1968b). Hereinafter, these deposits will be referred to, collectively, as the Galesburg/Page aquifer. The Galesburg/Page aquifer underlies an area of approximately 165 square miles in southeastern Steele County (Downey and Armstrong, 1977), 155 square miles in northwestern Cass County (Klausing, 1968b) and 85 square miles in southwestern Traill County (Jensen and Klausing, 1971), for a total areal extent of about 405 square miles. (Refer to Figure 1 and Figure C-1 for plan views of the aquifer's location and areal extent.) Geologically, the materials which comprise the Galesburg/Page aquifer are delta and off-shore (or near-shore) bar sediments deposited in glacial Lake Agassiz. Bluemle (1967) refers to these sediments as the Galesburg delta.

The lithology within the aquifer varies greatly and over short distances (Downey and Armstrong, 1977). In Steele County, the aquifer materials consist of lenticular sand and gravel deposits ranging in thickness from about 2 feet to 115 feet, interbedded with silt and clay. The saturated sand and gravel deposits have an average thickness of approximately 43 feet.

Information obtained from test holes in Steele County indicates the aquifer is composed of two units: an upper unit consisting of fine sand lenses, and a deeper unit consisting of interbedded sand and gravel (Downey and Armstrong, 1977). Klausing (1968b) also identified two units in Cass County. He describes the upper unit as a very fine to coarse sand, buried glaciofluvial deposit ranging from less than a foot to 78 feet thick. The lower unit is a buried outwash deposit composed predominantly of fine to medium sand ranging from less than a foot to 50 feet thick. Jensen and Klausing (1971) did not identify the two units in Traill County; however, this may be due to a lack of test holes that penetrated the deeper unit (Downey and Armstrong, 1977). In Traill County, the aquifer deposits are described as very fine to fine sand deposits, generally less than 50 feet thick (Jensen and Klausing, 1971).

The occurrence of glacial till at various locations throughout the stratigraphic sequence indicates the ice sheet advanced across the delta surface at times during its formation. Much of the aquifer also is covered with a layer of glacial till that serves as a confining layer. Klausing (1968b) estimates the thickness of the till overlying the Galesburg/Page aquifer in Cass County as from 9 to 80 feet.

Recharge to the Galesburg/Page aquifer is by direct infiltration of precipitation and snowmelt. Discharge is by flow to the Elm and South Branch Goose rivers, evapotranspiration and pumpage from wells (Downey and Armstrong, 1977).

The large areal extent and thickness of the Galesburg/Page aquifer would seem to indicate the potential for substantial development of groundwater resources. Downey and Armstrong (1977) estimate that yields to individual wells of 500 to 1,000 gpm might be expected from approximately one-fourth of the area of the aquifer. Development and utilization of the aquifer may, however, be limited by low permeability of the aquifer deposits. According to Jensen and Klausing (1971), only isolated portions of the aquifer in Traill County have permeable deposits thick enough to yield at least 10 gallons per minute.

Hankinson Aquifer

The Hankinson aquifer occupies a broad belt of sand and gravel in southeastern Richland County, extending from the Wild Rice River approximately 3 miles north of Hankinson southeastward to the South Dakota border. The aquifer has an areal extent of about 100 square miles (Baker and Paulson, 1967). (Refer to Figure 1 and Figure C-2 for plan views of the aquifers' location and areal extent.)

These sand and gravel deposits mark the higher beaches formed when Lake Agassiz drained to the south (Baker, 1967; Baker and Paulson, 1967), and extend from the Herman beach on the west to the Campbell beach on the east (Baker, 1967). Formerly included with the Sheyenne Delta, additional investigation has disclosed an area of till and lake clay separating the deposits (Baker and Paulson, 1967).

In the vicinity of Hankinson, the aquifer materials consist of well-sorted, fine sand approximately 100 feet thick. The deposits grade to poorly-sorted, coarser-grained sand and gravel to the south, and thin to only a few feet in thickness. The average thickness of the aquifer deposits is about 40 feet (Baker and Paulson, 1967).

The Hankinson aquifer is a water-table aquifer with water levels generally about 10 feet below the ground surface (Baker and Paulson, 1967). An estimated 330,000 acre-feet of water are available from the Hankinson aquifer. Infiltration of precipitation and snowmelt are the primary means of recharge to the aquifer; discharge is by evapotranspiration.

Kidder/Marstonmoor Plain Aquifer

The Kidder County aquifer complex, Tappen and Marstonmoor Plain aquifers are now referred to as the Kidder aquifer system, with the exception of the portion of the Marstonmoor Plain aquifer that extends into Stutsman County. The North Dakota State Water Commission still refers to this area as the Marstonmoor Plain aquifer (Parken, 2000). (Refer to Figure 1, Figure 3, Figure C-3 and Figure C-4 for plan views of the location and areal extent of the Kidder aquifer system and the Marstonmoor Plain aquifer. The cross-hatched areas in Figure 3 are the former Tappen and Marstonmoor Plain aquifers, now part of the Kidder aquifer system.) For the purposes of the groundwater monitoring program and this report, these areas collectively will be referred to as the Kidder/Marstonmoor Plain aquifer.

The hydrogeology varies greatly throughout the Kidder aquifer system. The aquifer is made up of several different intervals and lithology types. A portion of the aquifer is derived from glacial drift with low transmissivity, while parts of the aquifer are part of a large surficial outwash deposit. Hydraulically connected near-surface and subsurface intervals of sand and gravelly sand distributed within the glacial drift throughout Kidder County make up the largest portion of the Kidder aquifer system. This area was previously referred to as the Kidder County aquifer complex. It covers approximately 470 square miles throughout the county. The top of the aquifer in this area lies from 10 to 500 feet below the surface and averages 52 feet thick. There may be as many as five intervals of sand and gravel separated by till and/or lacustrine silty clay (Larson, 1987). Recharge to this portion of the aquifer is primarily from infiltration of precipitation. Discharge occurs through irrigation and into area lakes and sloughs. Using an

average thickness of 53 feet and a specific yield of 0.15, Larson (1987) estimated that 2,391,000 acre-feet of water is available from storage.

The portion of the Kidder aquifer system previously referred to as the Tappen aquifer underlies a broad, surficial outwash plain in east-central Kidder County that Bradley et al. (1963) described as one of the largest outwash plains in the state, covering about 64 square miles. It primarily consists of sand and gravelly sand underlain by glacial till and lacustrine silty clay. Aquifer thickness varies from 5 to 120 feet, with an average thickness of 26 feet. Water level measurements in observation wells indicate groundwater flow direction is from east to west. Recharge to the aquifer occurs from infiltrating precipitation, lateral flow from surficial outwash on the uplands and inflow from ephemeral surface water bodies. Discharge from the aquifer is mainly through evapotranspiration and irrigation. An estimated 160,000 acre-feet of water is available from storage in this portion of the aquifer.

The Marstonmoor Plain, located in western Stutsman County, is an extension of the outwash plains in Kidder County (Winters, 1963; Huxel and Petri, 1965). Winters (1963) refers to these deposits as pitted outwash plain based on the presence of several rounded or sub-rounded pits or depressions, some greater than a mile in length. Huxel and Petri (1965) refer to the aquifer associated with the underlying, thick deposits of sand and gravel as the Marstonmoor Plain aquifer. Formed of coalescing alluvial fans deposited by meandering, meltwater streams flowing from stagnant glacial ice to the north (Rau et al., 1962), the Marstonmoor Plain aquifer occupies approximately 35 square miles in western Stutsman County (Huxel and Petri, 1965).

According to Huxel and Petri (1965), the deposits of the Marstonmoor Plain aquifer consist of clean sand and gravel with a predominance of coarse material, suggesting high permeability. The coarser material is found in the northern part of the plain (Rau et al., 1962). The deposits range from 15 to 80 feet thick, with an average thickness of about 46 feet. The sand and gravel deposits overlie till or silt and clay or, in isolated instances, bedrock.

Groundwater in the aquifer is generally under water-table conditions (Bradley et al., 1963; Huxel and Petri, 1965); however, locally, artesian conditions may occur where the coarse-grained deposits are overlain by thin, fine-grained silt and clay deposits (Bradley et al., 1963).

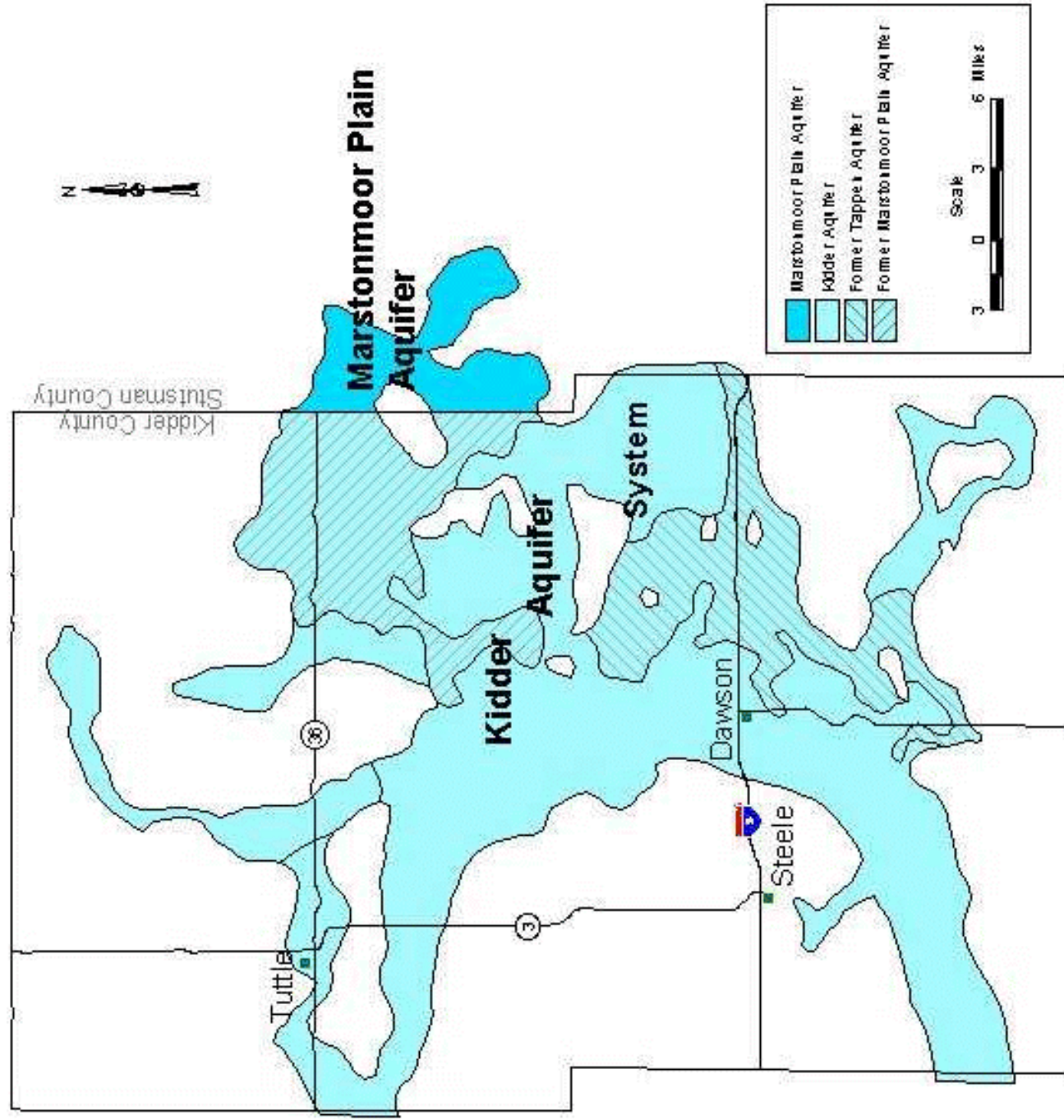


Figure 3. Location of Kidder aquifer system and Marstonmoor Plain aquifer showing areas formerly designated the Marstonmoor Plain and Tappen aquifers

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Recharge to the aquifer is primarily through direct infiltration of precipitation and snowmelt, as well as some lateral underflow from adjacent deposits; discharge is by evapotranspiration, springs and seepage into ponds and lakes (Huxel and Petri, 1965).

Based on an average saturated thickness of 28 feet, Huxel and Petri (1965) estimate that 90,000 acre-feet of water are in transient storage in the Stutsman County portion of the aquifer.

Milnor Channel Aquifer

Named for the town of Milnor, the Milnor Channel aquifer is located in southeastern Ransom, northeastern Sargent and southwestern Richland counties. (Refer to Figure 1, Figure C-2 and Figure C-5 for plan views of the aquifer's location and areal extent.)

The surface of the Milnor Channel aquifer is expressed by a long, somewhat winding, shallow valley extending from near the Sheyenne River valley in Ransom County generally southeastward into South Dakota (Baker and Paulson, 1967), a distance of approximately 50 miles. Near Hankinson, the channel curves to the south with the Herman beach bordering the channel on the east (Baker, 1967). Along its course, the Milnor Channel generally ranges in width from 1 to 3 miles. The areal extent of the channel in Ransom and Sargent counties is approximately 45 square miles (Armstrong, 1982) and in Richland County, approximately 40 square miles (Baker and Paulson, 1967).

The channel was probably formed as a meltwater trench, an ice-marginal course of the Sheyenne River, later abandoned (Baker and Paulson, 1967; Armstrong, 1982). The aquifer materials originated as terrace deposits, surficial outwash and abandoned channel deposits, and consists of predominantly sand and gravel with interbedded silt and clay (Armstrong, 1982).

The channel deposits in Richland County range from about 8 to 66 feet thick, with an average thickness of 40 feet (Baker and Paulson, 1967). The aquifer is a water-table aquifer, and the potentiometric surface is generally within 10 feet of the ground surface. Approximately 6 square miles of the Richland County portion of the aquifer are comprised of water-table lakes and ponds, and much of the remainder of the aquifer underlies low marshy ground (Baker and Paulson, 1967).

According to Armstrong (1982), the saturated thickness of the aquifer deposits in Ransom and Sargent counties ranges from less than a foot to 58 feet, with an average saturated thickness of approximately 35 feet. Although terrace deposits have been found buried beneath almost 80 feet of till and clay, in general, Armstrong (1982) reports the top of the aquifer as being from 3 to 33 feet below ground surface. Water levels in the aquifer are from near ground surface to approximately 35 feet below ground surface in Ransom and Sargent counties.

The Milnor Channel aquifer is recharged primarily through direct infiltration of precipitation and snowmelt (Baker and Paulson, 1967; Armstrong, 1982). In addition, Baker and Paulson (1967) attribute inter-aquifer movement of groundwater from the Brightwood aquifer as a source of recharge to the Milnor Channel, with possibly some contribution from adjacent beach and till deposits.

Water is discharged principally as underflow through the aquifer (Baker and Paulson, 1967) and by evapotranspiration, with additional discharge occurring through pumping wells and seepage into sloughs, lakes and the Sheyenne and Wild Rice rivers (Armstrong, 1982). Armstrong (1982) estimates approximately 150,000 acre-feet of water are available from the Ransom-Sargent County portion of the Milnor Channel aquifer. No estimates were given for that part of the aquifer located in Richland County.

Sheyenne Delta Aquifer

Occupying an area of approximately 750 square miles (Baker, 1967), the Sheyenne Delta forms a low plateau rising above the floor of glacial Lake Agassiz (Bluemle, 1979). The greatest portion of the Delta proper, approximately 500 to 550 square miles, is located in western Richland County (Baker, 1967; Baker and Paulson, 1967). The delta also occupies an estimated 230 square miles of Ransom County and the northeastern corner of Sargent County (Armstrong, 1982) and extends into south-central Cass County, where it has an areal extent of about 60 square miles (Klausing, 1968a). (Refer to Figure 1 and Figure C-5 for plan views of the aquifer's location and areal extent.)

The surface expression of the Sheyenne delta is characterized by sand hills or dunes that, locally, may exhibit a relief in excess of 75 feet (Bluemle, 1979), resulting in a markedly rolling topography (Baker, 1967). The dunes cover a generally east- or northeast-sloping, low-relief surface (Bluemle, 1979). The northeastern terminus of the delta is manifested by a prominent escarpment that is continuous with the Campbell beach and is generally believed to be a wave-cut feature formed during the Campbell stage of glacial Lake Agassiz (Klausing, 1968a). The escarpment rises approximately 75 to 100 feet above the lake plain. According to Bluemle (1979), the escarpment becomes less pronounced toward the south.

The sediments comprising the Sheyenne Delta and its associated aquifer consist of a lower unit of predominantly silt with interbedded clay that is generally overlain by sand (Baker and Paulson, 1967), probably deposited as turbidity-current sediments (Bluemle, 1979). The silt and clay unit is absent along the western margin of the delta in Ransom County and thickens eastward to a total thickness of more than 150 feet (Baker and Paulson, 1967). However, Baker (1967) also states that because an advancing delta is built out over existing lake-floor deposits in addition to its own bottomset beds that have essentially the same composition, it is impossible to distinguish the boundary between the two in test holes. These deposits generally overlie glacial till and are overlain by fluvial, deltaic sands deposited by a stream (or streams) spreading out over the surface (Bluemle, 1979). The deltaic sand unit is thickest in the west, where the approximate thickness near the Ransom-Richland County border is 100 feet, and thins to the east, where it is absent along the eastern edge of the delta (Baker and Paulson, 1967). The sand unit grades from medium and coarse sand in the western part of the delta to very fine sand in the eastern portion (Baker and Paulson, 1967). Covering the entire delta is a layer of surficial, eolian sand generally less than 10 feet thick but, in places, forming the well-developed dunes referred to earlier (Baker and Paulson, 1967). According to Klausing (1968b), the Cass County portion of the aquifer consists of two sand units separated by approximately 20 feet of silt.

The lower silt sediments are generally too fine-grained to yield sufficient water for pumping. Therefore, the main portion of the Sheyenne Delta aquifer is comprised of the deltaic sand unit and the overlying eolian sands (Baker and Paulson, 1967). The Sheyenne Delta aquifer is a water-table aquifer, and the potentiometric surface is generally less than 10 feet below ground surface (Baker and Paulson, 1967). In Cass County, semi-artesian conditions may be present in the lower sand as a result of the overlying silt deposit (Klausing, 1968b). The water table in the

Sheyenne Delta is considerably higher than both the surrounding lake plain and the Sheyenne River valley; therefore, the slope of the water table is toward the margins of the delta and the river valley (Baker and Paulson, 1967).

Recharge to the aquifer is by direct infiltration of precipitation and snowmelt (Baker and Paulson, 1967; Klausing, 1968b). Because of the irregular surface of the delta and the sandy soils, the majority of the precipitation is absorbed with little runoff (Baker and Paulson, 1967). Some recharge also may occur from flowing Dakota Formation wells (Armstrong, 1982).

Discharge from the aquifer is primarily by evapotranspiration, springs along the Sheyenne River valley and the edge of the delta, and pumping wells (Baker and Paulson, 1967).

Baker and Paulson (1967) estimate approximately four million acre-feet of water are stored in that portion of the Sheyenne Delta aquifer located in Richland County; however, because of the fine-grained nature of a large portion of the sediments, only one-half of that amount might be available to wells through pumping. In the Ransom and Sargent counties portion of the aquifer, approximately 900,000 acre-feet of water are in transient storage (Armstrong, 1982). No estimates were found for Cass County.

DESCRIPTION OF SITE CHARACTERISTICS

Site Inventory

A site inventory form was developed to collect data that would assist in the interpretation of the analytical results. The form was intended to record conditions around the well that may have an influence on the quality of the groundwater in the area. The form contains sections on well characteristics, activities performed and conditions around the well, as well as the parameters measured during the well-purging process. A copy of the form is included as Appendix A.

The site inventory form was completed by the field personnel who collected the sample(s) at each site. If the collection point was a private domestic, stock or irrigation well, or a public water supply well, an interview was conducted with the owner or other responsible person to obtain as

much site-specific information as was available. If the collection point was a government agency monitoring well, the collector completed as much of the inventory form as possible from field observation. When possible, drilling log information, such as well depth and diameter, was measured and verified. Water level measurements recorded were those measured at the time of sampling, or those currently reported by the owner in the case of private wells. Water levels from the drilling logs were not entered on the site inventory form unless more current information was unavailable. Site characteristics recorded were those within approximately one-eighth mile or less of the well.

Information from the site inventory forms was entered into a database that was used to relate the field information with the analytical results of the water sampling. The maps on the forms were not entered graphically in the database; however, information about the distance to potential contaminant sources was included. The field sheets are retained by the Division of Water Quality.

Well Characteristics

Approximately 65 percent of the wells sampled for this study were monitoring wells, 29 percent were private domestic wells and 5 percent were livestock wells. Most of these were small-diameter wells (less than 6 inches in diameter) and constructed of PVC casing. Other types of wells sampled include public water supply and irrigation wells constructed of a variety of materials. The wells varied in depth below ground surface and below the water table. The shallowest well sampled was slightly under 10 feet deep; the deepest well was 119 feet deep. A number of wells were screened across or very near the water table, while the deepest screened interval was approximately 110 feet below the water table. The age of the wells was generally less than 30 years because of the study restriction requiring all wells to have a well-construction log. Table 1 contains a summary of well characteristics for all five aquifers included in this report. Tables of well characteristics for each aquifer are located in Appendix D.

TABLE 1
General Well-Construction Statistics
For All Aquifers Sampled 1999

AQUIFER			#	PERCENT
GALESBURG/PAGE :			46	15.9
HANKINSON :			25	8.6
KIDDER/MARSTONMOOR PLAIN :			89	30.7
MILNOR CHANNEL :			61	21.0
SHEYENNE DELTA :			69	23.8
Total :			290	

DEPTH OF WELL	#	PERCENT
< 20 Ft. :	22	7.6 %
20 - 50 Ft. :	123	42.4 %
> 50 Ft. :	144	49.7 %
Unknown :	1	0.3 %

DIAMETER OF WELL	#	PERCENT
< 6 in. :	285	98.3 %
6 - 18 in. :	2	0.7 %
> 18 in. :	2	0.7 %
Unknown :	1	0.3 %

CASING MATERIAL	#	PERCENT
Plastic (PVC or ABS) :	261	90.0 %
Concrete/Brick/Stone :	0	0.0 %
Metallic :	27	9.3 %
Other :	2	0.7 %

DEPTH TO TOP OF SCREENED INTERVAL	#	PERCENT
< 20 Ft. :	35	12.1 %
20 - 50 Ft. :	137	47.2 %
> 50 Ft. :	112	38.6 %
Unknown :	6	2.1 %

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	PERCENT
< 10 Ft. :	38	13.1 %
10 - 30 Ft. :	112	38.6 %
> 30 Ft. :	125	43.1 %
Unknown :	15	5.2 %

TYPE OF WELL	#	PERCENT
Monitoring :	188	64.8 %
Private/Domestic :	84	29.0 %
Livestock :	14	4.8 %
Public Supply :	2	0.7 %
Irrigation :	1	0.3 %
Other :	1	0.3 %

is the number of wells in the category.
% is the percentage of wells in the category.

Site Characteristics

Wells were sampled from a variety of general settings, including fields, pastures, farmyards, Conservation Reserve Program (CRP) acres, roadsides and within town boundaries. Often the sites had characteristics of more than one type of general setting; for example, a well located on the boundary of a farmyard and a pasture, adjacent to a road ditch. In 1995, an additional data field was added to the site inventory form to include a secondary general setting to help account for wells with characteristics of more than one setting. Only wells located near chemical application areas or storage/mixing sites verified by the owner or applicator were recorded as such on the site inventory form and in the database. However, many more wells than verified in the field probably have had chemical application, storage or mixing performed near them. For instance, landowner information about chemical history for monitoring wells was rarely available.

WATER QUALITY ANALYSES

Analytes of Concern

According to a 1992 State Water Commission survey of North Dakota residents, the most important water-related issue is protecting groundwater from contamination. Agricultural chemicals are perceived as a threat to groundwater quality, and wide-spread contamination problems have occurred in other states. The main analytes of concern for this study are agricultural pesticides. The general inorganic chemical nature of each groundwater sample also was determined. Each sample was analyzed for general anions and cations, total nitrate plus nitrite as nitrogen (N), 39 base-neutral pesticides, 13 chlorinated pesticides and eight carbamate pesticides (Table 2). These three pesticide groups are included in the Safe Drinking Water Act, Phase II/V, sampling requirements. By analyzing for the same pesticides as community water systems, results from this study can be correlated more easily with community water system sampling results.

TABLE 2
Summary of Analytical Parameters

Analyte Group	Parameter Analyzed	NDDoH, DC Quantification Limit*	Sample Preservation	Holding Time
Minerals	Chloride	1.0 mg/l	Stored at 4 °C	14-28 days, varies with parameter
	Fluoride	0.01		
	Sulfate	3.0		
	Carbonate (CO ₃)	1.0		
	Bicarbonate (HCO ₃)	1.0		
	Hydroxide (OH)	1.0		
	Total Alkalinity	2.0		
	Total Hardness			
	TDS			
	Laboratory Conductivity			
	Laboratory pH			
	Percent Sodium			
	Sodium Adsorption Ratio			
	Turbidity			
ICP Metals	Sodium	0.1 mg/l	2 ml nitric acid to pH 2 and stored at 4 °C	6 months
	Magnesium	0.1		
	Potassium	1.0		
	Calcium	0.030		
	Manganese	0.002		
	Iron	0.007		
Nitrate	Nitrate plus Nitrite	0.05 mg/l (N)	2 ml sulfuric acid to pH 2 and stored at 4 °C	28 days

*Quantification limits for 1 full liter of clean sample.

TABLE 2 (continued)
Summary of Analytical Parameters

Analyte Group	Parameter Analyzed	NDDoH, DC Quantification Limit*	Sample Preservation	Holding Time
Pesticides	Aldrin	0.010 $\mu\text{g/l}$	Stored at 4 °C	7 days
Group I	BHC-Alpha	0.010		
Base-Neutral	BHC-Beta	0.010		
Organics	BHC-Delta	0.01		
	BHC-Gamma (Lindane)	0.010		
	DDD (or TDE)	0.010		
	DDE (degradate of DDT)	0.010		
	DDT	0.025		
	Dieldrin	0.010		
	Endosulfan I	0.010		
	Endosulfan II	0.010		
	Endosulfan Sulfate	0.010		
	Endrin	0.010		
	Endrin Aldehyde	0.02		
	Heptachlor	0.010		
	Heptachlor Epoxide	0.010		
	Methoxychlor	0.100		
	Diclofop (Hoelon)	1.00		
	Toxaphene	1.0		
	Chlordane (gamma)	0.010		
	Chlordane (alpha)	0.010		
	trans-Nonachlor	0.010		
	Endrin Ketone	0.025		
	Alachlor	0.200		
	Chlorpyrifos	1.00		
	Diazinon	0.10		
	Malathion	0.040		
	Ethyl Parathion	0.450		
	Methyl Parathion	0.450		
	Fenvalerate	0.400		
	Cyanazine	0.050		
	Triallate (Fargo)	0.010		
	Trifluralin (Treflan)	0.010		
	Simazine	0.450		
	Ethylfluralin	0.010		
	Atrazine	0.250		
	Pendimethalin (Prowl)	0.010		
	Metribuzin	0.020		
	Metolachlor	0.080		
Group II	2,4-D	0.10 $\mu\text{g/l}$	Stored at 4 °C	14 days
Chlorinated	Dicamba	0.10		
Herbicides	Dinoseb	0.20		
	MCPA	50.0		
	Picloram (Tordon)	0.10		
	2,4,5-T	0.15		
	2,4,5-TP (Silvex)	0.20		
	Pentachlorophenol	0.04		
	Acifluorfen	0.05		
	3,5 Dichlorobenzoic Acid	0.05		
	Bromoxynil	0.10		
	Bentazon	0.500		
	Dichlorprop	0.200		
Group III	Aldicarb	0.500 $\mu\text{g/l}$	1.33 ml carbamate buffer	28 days
Carbamates	Aldicarb Sulfoxide	0.50	(76% water, 13.3% mono-chloroacetic acid, 5.6% acetic acid, 5.1% potassium hydroxide)	
	Aldicarb Sulfone	0.50	to pH of 3.1 and stored between	
	Oxamyl	0.50	8 and 25 °C	
	Carbofuran	0.50		
	3-Hydroxycarbofuran	0.500		
	Methomyl	0.500		
	Carbaryl	0.50		

Significance of Selected Constituents

Interpretation of water quality depends upon many factors, including the intended use of the water. Several water-quality parameters may be detrimental to health or may cause undesirable aesthetic effects that may be considered unsatisfactory to some, while others may see little or no adverse effect for nearly all uses. In view of possible adverse and/or undesirable effects, the U.S. EPA has established drinking water regulations for concentrations of certain elements for water delivered to users of a public water system. These standards are classified as either primary or secondary drinking water regulations. Primary drinking water regulations are federally enforceable regulations for specific contaminants that are potentially harmful to human health and are defined by a Maximum Contaminant Level (MCL). Although MCLs are not enforced for private water supplies, they sometimes are applied as a cleanup goal when remediation of contaminated groundwater is needed. Secondary drinking water regulations vary from state to state and are not federally enforceable. In contrast to the primary regulations, the secondary regulations are defined by Secondary Maximum Contaminant Levels (SMCL) and are designed to protect public welfare. SMCLs are only recommended limits, and North Dakota public water systems are not required to comply with them.

Of the general chemistry parameters included in primary drinking water regulations, nitrate is of primary concern. Health effects associated with drinking nitrate-contaminated water include methemoglobinemia, commonly called "blue baby syndrome," in infants. The MCL for nitrate plus nitrite as nitrogen (N), hereinafter referred to as nitrate, is 10 mg/l. The potential health effects of nitrates are discussed in detail in Appendix E, the Health Advisory section.

Fluoride also is included in the primary drinking water regulations. Most fluoride compounds have a low solubility; therefore, fluoride usually occurs only in small amounts in natural water. Many municipal water systems add fluoride to their drinking water. Within certain limits, fluoride in drinking water has been shown to reduce the formation of cavities in children. Optimum fluoride concentrations are region-specific and are dependent upon the annual average of maximum daily air temperatures. An excess of fluoride may produce skeletal damage and dental fluorosis (a brownish discoloration of the teeth). The MCL for fluoride has been set at 4 mg/l; however, the SMCL is 2 mg/l. Some groundwater in North Dakota has naturally occurring fluoride concentrations that exceed the MCL.

The chemical constituents included under the secondary drinking water regulations of interest for this report include iron, manganese, sulfate and chloride and the physical properties of hardness and Total Dissolved Solids (TDS). Although generally not a health concern, elevated concentrations of these constituents may cause unpleasant side effects and/or aesthetic qualities.

Although high concentrations of iron and manganese do not appear to present a health hazard, concentrations greater than the recommended limits may cause rust, brown or black stains on laundry, plumbing fixtures, sinks and utensils. A metallic taste may be present, and the elements may affect the taste of beverages made from the water. The SMCL for iron is 0.3 mg/l, and 0.05 mg/l for manganese.

Water containing high levels of sulfate may have a laxative effect on people unaccustomed to the water. These effects vary with the individual and appear to last only until one becomes accustomed to drinking the water. High sulfate content also affects the taste of water and will form a hard scale in boilers and heat exchangers. For these reasons, the SMCL is 250 mg/l.

High concentrations of chloride may result in an objectionable salty taste in water and the corrosion of plumbing in the hot water system. Water high in chloride also may produce a laxative effect. An SMCL of 250 mg/l has been recommended for chloride, although at this level few people will notice a salty taste. Higher concentrations do not appear to cause adverse health effects. An increase in the normal chloride content of water may indicate possible contamination from human sewage, feedlots or industrial wastes.

The TDS content of water is a measure of the total quantity of mineral matter present. Generally, the more highly mineralized the water, the more distinctive its taste. Water high in minerals also may cause plumbing and appliances to deteriorate. It is recommended that water containing more than 500 mg/l dissolved solids not be used if other less-mineralized supplies are available. This does not mean, however, that water containing more than 500 mg/l concentration of TDS is unusable. Exclusive of most treated public supplies, the Missouri River, a few fresh lakes, and scattered wells, very few water supplies in North Dakota contain less than the SMCL of 500 mg/l. Conductivity, closely related to the TDS content of water, is a measure of the conductance of water to an electrical current. Conductivity is reported as micromhos per centimeter ($\mu\text{mhos/cm}$). TDS, in mg/l, is approximately 70 percent of the conductivity.

Hardness also is related to the TDS, and, as used in this report, refers to calcium and magnesium hardness. Hard water has no known adverse health effects and may be more palatable than soft water. Hard water is primarily of concern because it requires more soap for effective cleaning, forms scum and curd; causes yellowing of fabrics; toughens vegetables cooked in the water; and forms scales in boilers, water heaters, pipes and cooking utensils. Based on the U.S. Geological Survey classification (Klausing, 1979), water with a hardness of less than 60 mg/l (measured as calcium carbonate, CaCO_3) is considered soft, 61 to 120 mg/l is moderately hard, 121 to 180 mg/l is hard, and more than 180 mg/l is very hard. According to this classification, the hardness of good quality water should not exceed 270 mg/l. Because North Dakota groundwater is typically more mineralized than groundwater from other parts of the United States, the NDDoH-DC uses a hardness classification that is tailored to North Dakota groundwater. The NDDoH-DC classification provides an interpretation of hardness relative to North Dakota groundwater, as follows: less than 75 mg/l (measured as calcium carbonate, CaCO_3) is considered low hardness, 76 to 150 mg/l is fairly low, 151 to 225 mg/l is satisfactory, 226 to 325 mg/l is average, 326 to 450 mg/l is high, and more than 450 mg/l is very high. The interpretation of hardness for groundwater samples collected for the North Dakota Groundwater Monitoring Program is based upon the NDDoH-DC hardness classification. Water softer than 30 to 50 mg/l may be corrosive to piping, depending upon other factors such as pH, alkalinity, temperature and dissolved-oxygen content.

There is no MCL or SMCL for sodium; however, high sodium content in water may be a concern for those people who must limit their dietary intake of sodium. The contribution of sodium in drinking water is normally small compared to other sources, such as consumption of sodium chloride, or table salt. A standard for public water supplies of no more than 100 mg/l sodium has been suggested to ensure that the water supply adds no more than 10 percent of the average person's total sodium intake, or an even more conservative standard of 20 mg/l to protect heart and kidney patients. High concentrations of sodium will reduce the suitability of water for irrigation or for watering house plants. High concentrations of sodium in water may alter the soil chemistry and physical properties, possibly creating deleterious conditions for plant growth. Softening water by ion exchange or lime-soda ash processes will increase the sodium content.

Groundwater types, such as calcium bicarbonate and sodium chloride-bicarbonate, are classified based upon chemical analyses and represent the predominant cation (sodium, calcium or

magnesium) and anion (bicarbonate, sulfate or chloride) expressed in milliequivalents per liter. When two or more cations or anions are present in nearly equal concentrations, it is referred to as a mixed chemical type.

MONITORING RESULTS

A total of 290 wells from all five aquifers were sampled for general cation and anion chemistry, total nitrate plus nitrite, and 60 selected pesticides and pesticide-degradation products. The NDDoH-DC laboratory performed the analyses for all samples.

Forty-three wells, or approximately 15 percent of the wells sampled from the five aquifers, contained detectable concentrations of at least one pesticide. Pesticides were detected in samples from all five aquifers. The number of wells with pesticide detections in each aquifer was as follows: Sheyenne Delta, 17 wells; Hankinson, eight wells; Galesburg/Page, seven wells; Milnor Channel, six wells; and Kidder/Marstonmoor Plain aquifer, five wells. Table 3 lists all detections of pesticides, including the results of follow-up sampling.

Twenty pesticide compounds were positively identified by laboratory analysis: atrazine, bentazon, bromoxynil, carbaryl, cyanazine, 2,4-D, DDT, dicamba, dichlorprop, diclofop methyl, endosulfan I, endosulfan sulfate, endrin, endrin ketone, malathion, pentachlorophenol, picloram, simazine, 2,4,5-T and trifluralin. None of the pesticides were detected at concentrations above their respective HAL or MCL. The highest concentration of a detected pesticide was of 2,4-D at 5.11 $\mu\text{g/l}$, or 7.3 percent of its MCL set at 70 $\mu\text{g/l}$. The highest concentrations of detected pesticides in relation to a health-based standard were of cyanazine at 0.711 $\mu\text{g/l}$, or 71.1 percent of the HAL, and atrazine at 0.807 $\mu\text{g/l}$, or 26.9 percent of the MCL. These are significant because they exceeded the Prevention Action Level (PAL) of the Pesticide State Management Plan (PSMP) set at 25 percent of the MCL or HAL. If a pesticide is detected in groundwater at concentrations at or above the PAL, a second water sample will be collected from the well at least 30 days after the first sample. If the second sample confirms a detection above the PAL, the regulatory portion of the PSMP will be engaged. Both of the above wells were resampled in accordance with the PSMP; no pesticides were detected in either well upon resampling.

TABLE 3
Summary of Pesticide Detection Data
For All Aquifers Sampled in 1999

LOCATION/ WELL ID NUM.	AQUIFER	DATE	CHEMICAL DETECTED	HAL* or MCL(ug/l)	DETECTED CONC.(ug/l)	% of HAL or MCL	SAMPLE TYPE
14205422AAA	GALESBURG/PAGE	06/28/99	Trifluralin	5.000*	0.103	2.060	R
14205422AAA	GALESBURG/PAGE	09/27/99	Trifluralin	5.000*	0.120	2.400	R
14305415BBB2	GALESBURG/PAGE	06/29/99	Simazine	4.000	0.674	16.850	R
14305415BBB2	GALESBURG/PAGE	09/28/99	None				R
14305420ADD	GALESBURG/PAGE	06/23/99	None				R
14305420ADD	GALESBURG/PAGE	09/28/99	2,4-D	70.000	0.110	0.157	R
14305424DDD2	GALESBURG/PAGE	06/24/99	Picloram	500.000	0.060	0.012	R
14305424DDD2	GALESBURG/PAGE	09/28/99	None				R
14305432BBB	GALESBURG/PAGE	06/23/99	Pentachlorophenol	1.000	0.030	3.000	R
14305432BBB	GALESBURG/PAGE	09/28/99	None				R
14305517ABA	GALESBURG/PAGE	06/22/99	Dicamba	200.000*	0.050	0.025	R
14305517ABA	GALESBURG/PAGE	06/22/99	Picloram	500.000	0.600	0.120	R
14405506BBD	GALESBURG/PAGE	07/01/99	Picloram	500.000	0.060	0.012	R
12904826ABB	HANKINSON	06/09/99	Picloram	500.000	0.210	0.042	R
12904826ABB	HANKINSON	06/09/99	Pentachlorophenol	1.000	0.020	2.000	R
12904826ABB	HANKINSON	06/09/99	Dichlorprop	None	0.241		R
12904826ABB	HANKINSON	06/09/99	Bentazon	20.000*	0.331	1.655	R
12904826ABB	HANKINSON	09/23/99	Picloram	500.000	2.190	0.438	R
12904826ABB	HANKINSON	09/23/99	Bentazon	20.000*	1.300	6.500	R
12904916BAB	HANKINSON	06/09/99	Pentachlorophenol	1.000	0.050	5.000	B
12904916BAB	HANKINSON	09/24/99	None				R
13004929BCC	HANKINSON	06/08/99	Pentachlorophenol	1.000	0.050	5.000	B
13004929BCC	HANKINSON	09/23/99	None				R
13005006AAA2	HANKINSON	06/08/99	DDT	None	0.031		R
13005006AAA2	HANKINSON	09/23/99	None				R
13005008BAA2	HANKINSON	06/08/99	Picloram	500.000	0.080	0.016	R
13005008BAA2	HANKINSON	09/23/99	Picloram	500.000	0.070	0.014	R
13005009AAD2	HANKINSON	06/08/99	2,4-D	70.000	0.350	0.500	R
13005009AAD2	HANKINSON	06/08/99	Picloram	500.000	0.270	0.054	R
13005009AAD2	HANKINSON	09/23/99	None				R
13105027CDD2	HANKINSON	06/10/99	Cyanazine	1.000*	0.711	71.100	R
13105027CDD2	HANKINSON	09/23/99	None				R
13105032BCC	HANKINSON	06/08/99	2,4-D	70.000	5.110	7.300	R
13105032BCC	HANKINSON	06/08/99	2,4,5-T	70.000*	0.090	0.129	R
13105032BCC	HANKINSON	09/23/99	None				R
13907003DDD	KIDDER COUNTY	07/13/99	Picloram	500.000	0.160	0.032	R
13907114CBB	KIDDER COUNTY	08/04/99	Carbaryl	700.000*	1.000	0.143	R
13907114CBB	KIDDER COUNTY	10/21/99	None				R
14007132DAA	KIDDER COUNTY	07/18/99	Picloram	500.000	0.060	0.012	R
14007132DAA	KIDDER COUNTY	10/21/99	None				R
14207014BCC	KIDDER COUNTY	07/13/99	Picloram	500.000	0.150	0.030	R
14207014BCC	KIDDER COUNTY	10/21/99	Picloram	500.000	0.120	0.024	R
14207019CDD3	KIDDER COUNTY	08/03/99	Dichlorprop	None	0.410		R

Sample Type: R = Regular Sample; D = Duplicate Sample; B = Blank Sample

TABLE 3 (continued)
Summary of Pesticide Detection Data
For All Aquifers Sampled in 1999

LOCATION/ WELL ID NUM.	AQUIFER	DATE	CHEMICAL DETECTED	HAL* or MCL(ug/l)	DETECTED CONC.(ug/l)	% of HAL or MCL	SAMPLE TYPE
13005007AAA	MILNOR CHANNEL	06/03/99	Picloram	500.000	0.560	0.112	R
13005010CCC	MILNOR CHANNEL	06/10/99	Pentachlorophenol	1.000	0.050	5.000	R
13005010CCC	MILNOR CHANNEL	09/23/99	None				R
13005211ADA	MILNOR CHANNEL	05/25/99	Picloram	500.000	0.270	0.054	R
13005211ADA	MILNOR CHANNEL	10/25/00	Picloram	500.000	0.200	0.040	R
13105136BBC	MILNOR CHANNEL	06/03/99	Picloram	500.000	0.160	0.032	R
13105136BBC	MILNOR CHANNEL	09/24/99	Picloram	500.000	0.130	0.026	R
13205336BBC	MILNOR CHANNEL	05/26/99	Dicamba	200.000*	0.130	0.065	R
13205336BBC	MILNOR CHANNEL	10/25/00	None				R
13205409CBC	MILNOR CHANNEL	05/25/99	Dicamba	200.000*	0.060	0.030	R
13205409CBC	MILNOR CHANNEL	05/25/99	Dicamba	200.000*	0.080	0.040	D
13205409CBC	MILNOR CHANNEL	09/22/99	None				R
13305118ABB	SHEYENNE DELTA	05/04/99	Picloram	500.000	0.100	0.020	R
13305118ABB	SHEYENNE DELTA	09/21/99	Picloram	500.000	0.100	0.020	R
13305311BBB2	SHEYENNE DELTA	04/21/99	Picloram	500.000	0.170	0.034	R
13305311BBB2	SHEYENNE DELTA	04/21/99	Pentachlorophenol	1.000	0.120	12.000	R
13305311BBB2	SHEYENNE DELTA	04/21/99	Bromoxynil	None	0.027		R
13305311BBB2	SHEYENNE DELTA	09/22/99	None				R
13405120AAA	SHEYENNE DELTA	05/05/99	Picloram	500.000	0.250	0.050	R
13405120AAA	SHEYENNE DELTA	09/22/99	Picloram	500.000	0.220	0.044	R
13405304AABAAB1	SHEYENNE DELTA	04/27/99	Picloram	500.000	0.200	0.040	R
13405312BBB2	SHEYENNE DELTA	04/22/99	Pentachlorophenol	1.000	0.120	12.000	R
13405312BBB2	SHEYENNE DELTA	09/21/99	None				R
13405314DCCCCC1	SHEYENNE DELTA	04/21/99	DDT	None	0.020		R
13405314DCCCCC1	SHEYENNE DELTA	04/21/99	Endrin	2.000	0.046	2.300	R
13405314DCCCCC1	SHEYENNE DELTA	04/21/99	2,4-D	70.000	0.280	0.400	R
13405314DCCCCC1	SHEYENNE DELTA	04/21/99	Picloram	500.000	0.070	0.014	R
13405314DCCCCC1	SHEYENNE DELTA	04/21/99	2,4,5-T	70.000*	0.100	0.143	R
13405314DCCCCC1	SHEYENNE DELTA	04/21/99	Pentachlorophenol	1.000	0.040	4.000	R
13405314DCCCCC1	SHEYENNE DELTA	04/21/99	Dichlorprop	None	0.490		R
13405314DCCCCC1	SHEYENNE DELTA	04/21/99	Bentazon	20.000*	0.270	1.350	R
13405314DCCCCC1	SHEYENNE DELTA	09/21/99	None				R
13505119DAAAAA1	SHEYENNE DELTA	04/15/99	DDT	None	0.036		R
13505119DAAAAA1	SHEYENNE DELTA	04/15/99	Endrin	2.000	0.075	3.750	R
13505119DAAAAA1	SHEYENNE DELTA	04/15/99	Endrin Ketone	2.000	0.016	0.800	R
13505119DAAAAA1	SHEYENNE DELTA	04/15/99	Atrazine	3.000	0.807	26.900	R
13505119DAAAAA1	SHEYENNE DELTA	09/21/99	None				R
13505134BCCCCB1	SHEYENNE DELTA	04/15/99	Diclofop-methyl	None	0.350		R
13505134BCCCCB1	SHEYENNE DELTA	09/21/99	None				R
13505204BDBBBD	SHEYENNE DELTA	04/14/99	Endosulfan I	None	0.010		D
13505204BDBBBD	SHEYENNE DELTA	09/21/99	None				R
13505210ACA2	SHEYENNE DELTA	04/22/99	Pentachlorophenol	1.000	0.090	9.000	R
13505210ACA2	SHEYENNE DELTA	09/21/99	None				R
13505227CCC2	SHEYENNE DELTA	04/22/99	Pentachlorophenol	1.000	0.070	7.000	R
13505227CCC2	SHEYENNE DELTA	09/20/99	None				R

Sample Type: R = Regular Sample; D = Duplicate Sample; B = Blank Sample

TABLE 3 (continued)
Summary of Pesticide Detection Data
For All Aquifers Sampled in 1999

LOCATION/ WELL ID NUM.	AQUIFER	DATE	CHEMICAL DETECTED	HAL* or MCL(ug/l)	DETECTED CONC.(ug/l)	% of HAL or MCL	SAMPLE TYPE
13505233DAAAAA1	SHEYENNE DELTA	04/22/99	Pentachlorophenol	1.000	0.110	11.000	R
13505233DAAAAA1	SHEYENNE DELTA	09/20/99	None				R
13605124DADDAB1	SHEYENNE DELTA	04/13/99	Picloram	500.000	0.390	0.078	R
13605124DADDAB1	SHEYENNE DELTA	10/26/00	Picloram	500.000	0.260	0.052	R
13605210ADD2	SHEYENNE DELTA	05/05/99	Picloram	500.000	1.260	0.252	R
13605210ADD2	SHEYENNE DELTA	09/22/99	None				R
13605228ABBBBB	SHEYENNE DELTA	04/14/99	DDT	None	0.010		R
13605228ABBBBB	SHEYENNE DELTA	04/14/99	Endosulfan Sulfate	None	0.010		R
13605228ABBBBB	SHEYENNE DELTA	09/20/99	None				R
13605229DDD	SHEYENNE DELTA	04/23/99	Picloram	500.000	0.130	0.026	R
13605229DDD	SHEYENNE DELTA	04/23/99	2,4,5-T	70.000*	0.050	0.071	R
13605229DDD	SHEYENNE DELTA	04/23/99	Pentachlorophenol	1.000	0.230	23.000	R
13605229DDD	SHEYENNE DELTA	09/21/99	None				R
13705228CAA	SHEYENNE DELTA	05/04/99	Malathion	200.000*	0.379	0.190	R
13705228CAA	SHEYENNE DELTA	05/04/99	Malathion	200.000*	0.460	0.230	D
13705228CAA	SHEYENNE DELTA	09/21/99	None				R

Sample Type: R = Regular Sample; D = Duplicate Sample; B = Blank Sample

Pentachlorophenol was detected in samples from 12 wells at concentrations ranging from 2 percent to 23 percent of the MCL. The laboratory reported seven of the pentachlorophenol detections as probably being due to laboratory contamination. Four of the remaining detections, two of which were in field blank samples, were reported as unconfirmed detections. The pesticide analyses are generally performed using a gas chromatograph. When a pesticide is detected, its presence is confirmed by analyzing the sample on a second column. An unconfirmed detection is one in which the pesticide is not detected in the second column. In addition to the pentachlorophenol, several other pesticide detections were unconfirmed detections. Pentachlorophenol was not detected in any of the 12 wells when resampled.

Other pesticides detected at concentrations greater than 1 percent of their MCL or HAL were simazine, 16.85 percent; 2,4-D, 7.3 percent; endrin, two detections at 2.3 percent and 3.75 percent of the MCL; bentazon, three detections, including a regular and a follow-up sample from the same well, at 1.655 percent and 6.5 percent of the MCL, respectively, and a sample from another well at 1.35 percent of the MCL; and trifluralin in both a regular and a follow-up sample from the same well at 2.06 percent and 2.4 percent of the HAL, respectively. All other detections were less than 1 percent of the MCL or HAL.

Picloram, found in 20 wells, was the pesticide detected most frequently and the pesticide most often confirmed in follow-up samples. This was followed by pentachlorophenol, with detections in samples from 12 wells. Other pesticides detected in multiple wells were 2,4-D, detected in four wells; DDT, dicamba, dichlorprop and 2,4,5-T, each detected in three wells; and endrin and bentazon, each detected in two wells. All other pesticides were found in only one well. A discussion of the pesticide detections in each well follows in sections addressing individual aquifers.

The three detections of DDT are highly suspect and may be due to sample contamination rather than from actual use or application of the chemical. In the United States, all uses, except emergency public health uses and a few other uses permitted on a case-by-case basis, were canceled as of Jan. 1, 1973 (Farm Chemical Handbook, 2000). Although there is evidence that DDT is very persistent in the environment, it adsorbs very strongly to soil and will not leach appreciably to groundwater, even within the water column itself (Chemical Abstract Services CAS # 50293).

Fifty-nine wells, or 20 percent of the 290 wells sampled, had nitrate concentrations greater than the detection limit of 0.05 mg/l (N) in at least one sample collected. Almost two-thirds of the samples with detectable nitrate were at trace levels near the detection limit. Samples from five wells, or 1.7 percent of the total wells sampled, were greater than the 10 mg/l(N) MCL. A discussion of the nitrate detections in each well that exceeded the MCL follows in sections addressing individual aquifers. Prior to the 1995 monitoring year, a nitrate detection level of greater than or equal to 0.02 mg/l was used for reporting nitrate detections. For this report, however, all of the nitrate detection data has been corrected to the current standard minimum detection level of greater than or equal to 0.05 mg/l (N).

Complete general inorganic chemical results, including nitrates, are listed for each aquifer in Appendix B. Also included with the analyses are the minimum, maximum, mean, median and standard deviation values for each parameter. Aquifer maps showing the sample locations are found in Appendix C. Descriptions of the characteristics and possible health effects of the detected pesticides and nitrates are found in Appendix E.

Galesburg/Page Aquifer

A total of 55 samples were collected from 46 wells in the Galesburg/Page aquifer. Earlier studies identified the water in the aquifer as being either a calcium bicarbonate or calcium sulfate type (Jensen and Klausing, 1971; Downey and Armstrong, 1977), a finding supported by this study. On average, it is very high in iron and manganese and within the recommended levels for sodium, sulfate and total dissolved solids. Median hardness was high at 433 mg/l as CaCO_3 .

Pesticides were detected in samples from seven wells, 15 percent of the wells sampled in the Galesburg/Page aquifer.

Monitoring wells 14305424DDD2 and 14405506BBD had picloram concentrations of $0.06 \mu\text{g/l}$, or 0.012 percent of the $500 \mu\text{g/l}$ MCL. A follow-up sample collected three months later in well 14305424DDD2 showed no detections. Well 14405506BBD was not resampled in 1999; however, in 1994, picloram also was detected in the well at a concentration of $0.28 \mu\text{g/l}$. This was the only pesticide detection in the Galesburg/Page aquifer in 1994. This well is a 4-inch-diameter domestic well, 23 feet deep, with a water level 6 feet below the ground surface when the well was constructed. The primary setting of the well is in a farmyard and near crop land. Well 14305424DDD2 was not sampled in 1994. It is a 1.25-inch-diameter observation well screened from 80 to 86 feet, with a water level less than 5 feet below the ground surface at the time the samples were taken. It is located in a road ditch near cropland.

Well 14205422AAA had an initial trifluralin detection at a concentration of $0.103 \mu\text{g/l}$, or 2.06 percent of the $5.0 \mu\text{g/l}$ HAL. Trifluralin also was detected in a resample collected three months later at a concentration of $0.12 \mu\text{g/l}$, or 2.4 percent of the HAL. This is a 1.25-inch-diameter monitoring well constructed of PVC, with a screened interval of 58 to 64 feet. The depth to water in the well was about 5 feet below the ground surface. The primary setting of the well is a field.

Simazine was initially detected in well 14305415BBB2 at a concentration of $0.674 \mu\text{g/l}$, or 16.85 percent of the $4.0 \mu\text{g/l}$ MCL. There was no detection of simazine in the follow-up sample collected three months after the initial sample. This is a 1.25-inch-diameter monitoring well constructed of ABS and screened from 84 to 90 feet. The well is located in a roadside ditch

within 100 feet of cropland.

Well 14305420ADD had a detection of 2,4-D at a concentration of 0.11 $\mu\text{g/l}$, or 0.157 percent of the 70 $\mu\text{g/l}$ MCL. There was no follow-up sample collected from this well; however, a sample taken three months previously showed no detection of 2,4-D. Although there were no pesticides detected when the well was initially sampled, it was resampled for quality control purposes; 2,4-D was detected in the resample from the well. This well is constructed of 1.25-inch-diameter PVC and screened from 78 to 81 feet. The water level was about 3 feet below the ground surface. The primary setting of the well is a roadside ditch within 100 feet of cropland.

An initial sample collected from well 14305432BBB had a pentachlorophenol concentration of 0.03 $\mu\text{g/l}$ or 3.0 percent of the MCL, set at 1.0 $\mu\text{g/l}$; however, there were no pesticides detected in the well when the follow-up sample was collected three months later. This well is a 1.25-inch-diameter well constructed of PVC casing. The well is screened from 73 to 78 feet, and had a water level of approximately 5.5 feet below the ground surface when the sample was collected. The primary location of the well is in a roadside ditch near row crops and within one-eighth mile of a septic system.

In 1999, two pesticides were detected in well 14305517ABA. Picloram was detected at a concentration of 0.6 $\mu\text{g/l}$, or 0.12 percent of the MCL, and dicamba at a concentration of 0.05 $\mu\text{g/l}$, or 0.025 percent of the 200 $\mu\text{g/l}$ HAL. These results were not able to be confirmed with a follow-up sample. Although not sampled in 1994, the well was sampled in 1995, at which time bentazon and 2,4-D were detected. Bentazon was confirmed in the well in a resample collected later that year. This is a 24-inch-diameter well constructed of steel casing, with a screened interval of 10 to 38 feet below ground surface. The reported water level when the well was constructed was approximately 10 feet below the ground surface. The well, used seasonally for watering livestock, is located in a farmyard within 100 feet of a fertilizer mixing and loading area and a septic system. This well also had nitrate detected at a concentration above the MCL, as discussed below. The pesticide and nitrate detections may be attributable to the large diameter of the well. Typically, large-diameter wells are more susceptible to point source contamination.

Seven wells, about 15 percent, of the 46 wells sampled in the Galesburg/Page aquifer contained detectable concentrations of nitrate. The concentration in one well, 14305517ABA, described in

the preceding section on pesticide detections, was greater than the 10 mg/l (N) MCL. The nitrate concentration detected in the well in 1999 was 16.4 mg/l (N); the well also was sampled in 1995, with initial sample and resample nitrate concentrations of 26.1 and 30.3 mg/l (N), respectively. Although not sampled in 1994, this well is included with the statistical representations of that data. Nitrate concentrations in the remaining six wells ranged from 0.05 to 4.75 mg/l (N), with concentrations in five of the six wells less than 1 mg/l (N).

In all, 11 of the 15 wells initially sampled in the Galesburg/Page aquifer in 1994 were resampled in 1999. Some of the wells could not be resampled because of restricting factors such as weather; some could not be found and were presumably either abandoned or accidentally destroyed; a few may have been damaged or were missing caps; and, in some instances, attempts to contact the landowner for permission to sample a private well were unsuccessful. Figure 4 compares all of the wells sampled in 1994 and 1999 (the two columns on the left) and the 11 wells that were sampled both years (the two columns on the right). The number of wells listed at the top of the bar graphs represents the total number of wells sampled in that category.

As shown in Figure 4, the overall percentage of wells with nitrate detections decreased from 1994 to 1999, as did the percentages of wells for all concentration intervals. The observed decreases may be due to the greater number of wells sampled in 1999 -- 46 wells compared to 15 wells in 1994. When comparing only the 11 wells sampled in both 1994 and 1999, the overall percentage of wells with nitrate detections also decreased. The percentages of wells with high- and intermediate-concentration detections stayed the same, while the percentage of wells with low-concentration detections decreased. This is due to a change in status in only one well, 14405327ABB, which had nitrate detected at 0.22 mg/l in 1994.

Table 4 lists all 11 wells sampled in both years, as well as other years if applicable, along with the nitrate concentrations detected in each well. The actual concentrations detected in 1994 are listed in the table, although all graphs have been adjusted to the standard detection limit of 0.05 mg/l (N) currently used.

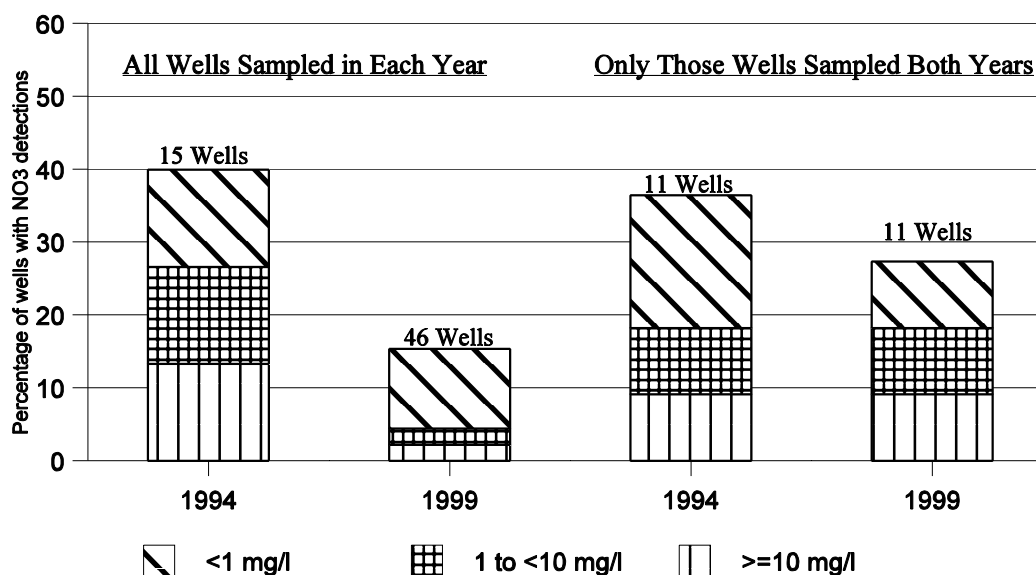


FIGURE 4. Graph of nitrate detections in the Galesburg/Page aquifer for the years 1994 and 1999

TABLE 4
Summary of Nitrate Concentrations
in the Wells in the Galesburg/Page Aquifer Sampled in Both 1994 and in 1999
 In milligrams per liter [mg/l] (N)

Well ID #	Type of Well	1994	1995	1999
1. 142 054 10 CDD	Domestic	ND	N/A	ND
2. 143 055 17 ABA	Domestic	N/A	26.1 / 30.3	16.4
3. 144 053 27 ABB	Domestic	0.22	N/A	ND
4. 144 053 29 ABD	Stock	ND	N/A	ND
5. 144 054 34 CCC2	Domestic	ND	N/A	ND
6. 144 055 06 BBD	Domestic	ND	ND	ND
7. 144 055 36 BC	Domestic	ND	N/A	ND
8. 145 054 22 AAA	Monitoring	0.02	N/A	ND
9. 145 055 17 CBC	Domestic	4.58	N/A	4.75
10. 146 053 29 DCC	Public	ND	N/A	ND
11. 146 053 32 ACB	Public	0.22	N/A	0.12

ND = Not Detected; N/A = Not Applicable

Hankinson Aquifer

Thirty-three samples were collected from 25 wells in the Hankinson aquifer. The water is generally a calcium bicarbonate type. The samples were high in iron and manganese, low in sodium and within recommended limits for TDS, chloride and sulfate. Although median TDS was in the recommended limit of 500 mg/l, 14 wells, or more than one-half of the wells sampled in the Hankinson aquifer, exceeded this limit. Median hardness was high at 391 mg/l as CaCO_3 .

Pesticides were detected in samples from eight wells, or 32 percent of the wells sampled in the Hankinson aquifer. Pentachlorophenol was detected in blank samples collected along with regular samples at two of the wells, 12904916BAB and 13004929BCC, both at concentrations of 0.05 $\mu\text{g/l}$. No pesticides were detected in either the regular samples or in follow-up samples collected from the wells. Both wells are 4-inch-diameter domestic wells ranging from 31 to 50 feet in depth. Well 12904916BAB is constructed of PVC casing and is located within 100 feet of row crops and one-eighth mile of a septic system. There also was a small depression around this well. Well 13004929BCC is constructed of stainless steel casing and is located within 100 feet of pasture and surface water and within one-eighth mile of a septic system.

Well 13005006AAA2 had a DDT detection of 0.031 $\mu\text{g/l}$ in the initial sample; however, no pesticides were detected in a follow-up sample collected three months later. There currently are no MCLs or HALs set for DDT. This is probably due to the fact it has been off the market for so many years. This well is a 2-inch-diameter monitoring well constructed of PVC casing and screened from 58 to 63 feet below the ground surface. It had a water level of about 5.5 feet below ground surface when the sample was taken. The well is located in a roadside ditch near row crops.

Monitoring well 13005008BAA2 had picloram detections in both the initial sample collected and in the follow-up sample at concentrations of 0.08 and 0.07 $\mu\text{g/l}$, respectively. This well is a 2-inch-diameter well constructed of PVC and screened from 45 to 50 feet. It is located in a roadside ditch within 100 feet of row crops.

Two pesticides were detected in monitoring well 13005009AAD2. Picloram was detected at 0.27 $\mu\text{g/l}$, 0.054 percent of the 500 $\mu\text{g/l}$ MCL, and 2,4-D was detected at a concentration of 0.35

$\mu\text{g/l}$, or 0.5 percent of the 70 $\mu\text{g/l}$ MCL. No pesticides were detected in the follow-up sample collected from the well. The primary location of the well is a roadside ditch near a pasture and within 100 feet of row crops. The well is constructed of 2-inch-diameter PVC casing and screened from 35 to 40 feet. The water level at the time the well was sampled was about 7 feet below ground surface.

Two pesticides also were detected in well 13105032BCC: 2,4-D was detected at a concentration of 5.11 $\mu\text{g/l}$, or 7.3 percent of the 70 $\mu\text{g/l}$ MCL, and 2,4,5-T at a concentration of 0.09 $\mu\text{g/l}$, or 0.129 percent of the 70 $\mu\text{g/l}$ HAL. Neither pesticide was detected in the follow-up sample from the well collected approximately three months later. This well is a 4-inch-diameter monitoring well constructed of PVC casing and screened from 51 to 76 feet. The water level in the well at the time the sample was collected was 10 feet below the surface. The primary location of the well is a pasture.

Cyanazine was initially detected in monitoring well 13105027CDD2 at a concentration of 0.711 $\mu\text{g/l}$, or 71 percent of the 1.0 $\mu\text{g/l}$ HAL; however, no pesticides were detected in a follow-up sample collected from the well. This well is constructed of 2-inch-diameter PVC casing. The well is screened from 39 to 44 feet, and the water level in the well was approximately 1 foot below the ground surface when the sample was collected. The well is near row crops and pasture.

In 1994, five of the 20 wells sampled in the Hankinson aquifer, or 25 percent, had detections of pesticides. Three of the five wells were again sampled in 1999. One of the three wells also had detections of pesticides in 1999. Well 12904826ABB had four pesticide species detected in the initial sample collected from the well in 1999. Picloram, pentachlorophenol, dichlorprop and bentazon were detected at concentrations of 0.21, 0.02, 0.241 and 0.331 $\mu\text{g/l}$, respectively. Picloram and bentazon were confirmed in a follow-up sample collected approximately three months later at concentrations of 2.19 $\mu\text{g/l}$ (0.438 percent of the MCL) and 1.3 $\mu\text{g/l}$ (6.5 percent of the HAL), respectively. The sample collected from this well in 1994 also contained four pesticide species: trifluralin, 2,4-D, picloram and bromoxynil. None were detected in the follow-up sample collected from the well in 1995. This well is a 4-inch-diameter domestic well constructed of steel casing. The screened interval is from 20 to 24 feet. The well is located in a farmyard within 100 feet of a disposal area, feedlot and septic system.

Six wells, or 24 percent of the wells sampled in the Hankinson aquifer in 1999, contained detectable nitrate concentrations. None of these wells had concentrations equal to or greater than the MCL of 10 mg/l (N). Nitrate concentrations in the six wells ranged from 0.08 to 2.46 mg/l (N), with concentrations in five of the six wells less than 1 mg/l (N).

Twelve of the 20 wells sampled in 1994 were resampled in 1999. Eight wells could not be resampled for reasons described previously in this report. Figure 5 compares the percentages of nitrate detections in the Hankinson aquifer for the years 1994 and 1999. In 1994, all 20 wells sampled in the Hankinson aquifer had detected concentrations of nitrate. All the concentrations were below the 10 mg/l (N) MCL. As shown in Figure 5, the overall percentages of wells with nitrate detections decreased by nearly 80 percent from 1994 to 1999. When comparing only the 12 wells sampled in both years, none had nitrate detections in 1999. Table 5 lists all 12 wells sampled in the Hankinson aquifer in both years, along with the nitrate concentrations detected in the wells.

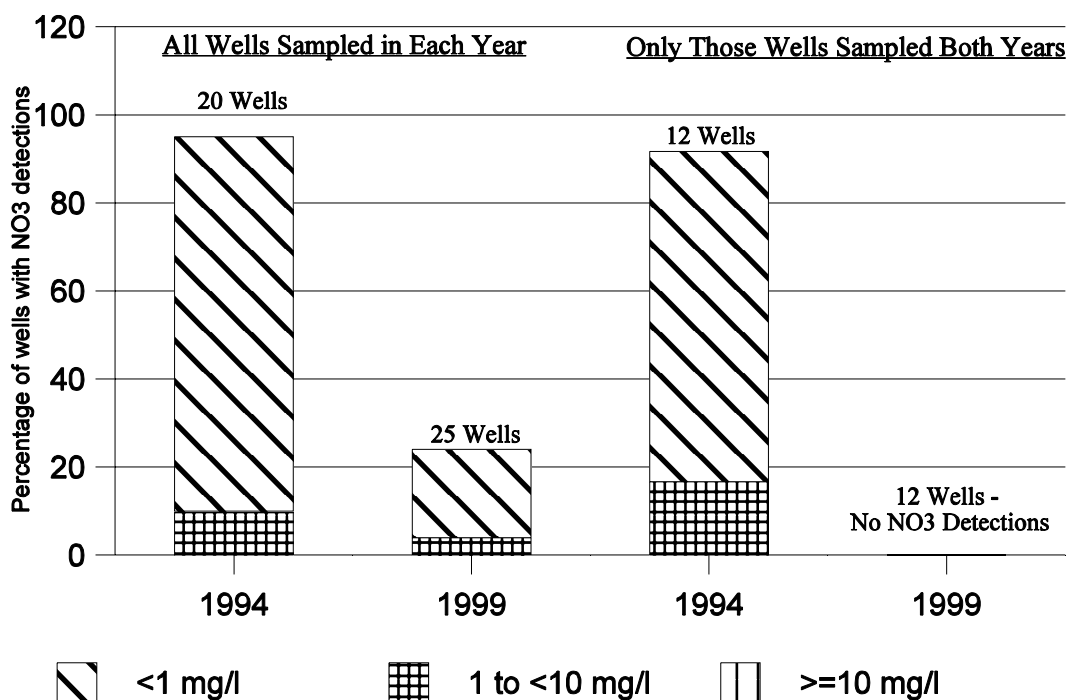


FIGURE 5. Graph of nitrate detections in the Hankinson aquifer for the years 1994 and 1999

TABLE 5
Summary of Nitrate Concentrations
in the Wells in the Hankinson Aquifer Sampled in Both 1994 and 1999

In milligrams per liter [mg/l] (N)

Well ID #	Type of Well	1994	1999
1. 129 048 26 ABB	Domestic	2.73	ND
2. 129 048 33 DDC	Domestic	0.30	ND
3. 129 049 06 ACD	Domestic	0.14	ND
4. 129 049 08 CDD	Stock	4.91	ND
5. 129 049 10 BDAD	Domestic	0.04	ND
6. 129 049 13 BBB	Domestic	0.10	ND
7. 129 049 16 BAB	Domestic	0.07	ND
8. 129 049 20 BBB	Domestic	0.07	ND
9. 129 049 33 BAC	Domestic	0.10	ND
10. 130 049 06 BBD	Domestic	0.06	ND
11. 130 049 29 BCC	Domestic	0.08	ND
12. 130 049 30 ADD	Domestic	0.07	ND

ND = Not Detected

Kidder/Marstonmoor Plain Aquifer

Ninety-two samples were collected from 89 wells in the Kidder/Marstonmoor Plain aquifer. As stated previously, the Tappen aquifer, sampled in 1996, is now included in the Kidder aquifer system. All references to previous monitoring results also include results from the 1996 monitoring of the Tappen aquifer. The water is generally a calcium bicarbonate type. The samples were high in iron and manganese, low in sodium and chloride and within the recommended limits for TDS and sulfate. Median hardness was average at 320 mg/l as CaCO₃.

Pesticides were detected in five of the 89 wells sampled in the Kidder/Marstonmoor Plain aquifer in 1999. This is about 6 percent of the wells sampled in the aquifer. Picloram was the pesticide detected in three of the wells. Well 14207014BCC contained a picloram concentration of 0.15 µg/l, or 0.03 percent of the 500 µ/l MCL. Picloram also was detected in a follow-up sample from the well at 0.12 µg/l, or 0.024 percent of the MCL. No pesticides were detected in the well

when it was sampled in 1994. The picloram concentration in the initial sample collected from well 14007132DAA was 0.06 $\mu\text{g/l}$, or 0.012 percent of the MCL. There were no pesticides detected in a follow-up sample collected from the well. The third well, 13907003DDD, had an initial detection of picloram at a concentration of 0.16 $\mu\text{g/l}$, or 0.032 percent of the MCL. A follow-up sample was not collected from this well. Two of the wells with picloram detections in the Kidder/Marstonmoor aquifer are domestic wells, and the third well is used for watering livestock. All three wells are 4-inch-diameter, two are constructed of PVC and one of stainless steel. Well depths ranged from 65 to 76 feet below the ground surface, and the top of the screened intervals ranged from 45 to 66 feet below the ground surface. When these wells were constructed, the static water levels ranged from 3 to 50 feet below the ground surface. All three wells were located within one-eighth mile of septic systems and one was within 100 feet of a feedlot.

Well 14207019CDD3 had a dichlorprop concentration of 0.41 $\mu\text{g/l}$ in a regular sample collected from the well. Dichlorprop was not detected in a duplicate sample collected at the same time. A follow-up confirmation sample was not collected from the well. This well is a 2-inch-diameter monitoring well constructed of PVC casing. The screened interval is from 33 to 38 feet below the ground surface, and the water level was approximately 15 feet below the ground surface when the well was sampled. The well was reportedly near surface water, hay land and CRP.

Carbaryl was detected in well 13907114CBB at a concentration of 1.0 $\mu\text{g/l}$, or 0.143 percent of the 700 $\mu\text{g/l}$ HAL. Carbaryl was not detected in a follow-up sample collected from the well. This well also was sampled in 1996; no pesticides were detected at that time. This is a 4-inch-diameter domestic well constructed of PVC. It is screened from 35 to 55 feet and had a static water level of 30 feet below the ground surface when the well was constructed. The well is located in a farmyard near a feedlot, septic system and hay land.

No pesticides were detected when portions of the Kidder/Marstonmoor Plain aquifer were previously sampled, the Marstonmoor Plain aquifer in 1994 and the Tappen aquifer in 1996. Four of the five wells with pesticide detections in 1999 also were sampled during one of those earlier sampling periods.

Seventeen wells, or about 19 percent of the wells sampled in the Kidder/Marstonmoor Plain aquifer, contained detectable nitrate concentrations. Three wells, approximately 3 percent, had concentrations equal to or greater than the MCL of 10 mg/l (N). Two of the wells, 14007124DDD3 and 14007127ABB2, are 2-inch-diameter monitoring wells, 50 and 33 feet deep, respectively, and had respective nitrate concentrations of 10.5 and 10.4 mg/l (N). The third well, 1407119DDD3, had a nitrate concentration of 11.9 mg/l (N). This well is a 1.25-diameter monitoring well constructed of PVC and screened from 16 to 19 feet below the surface. The water level was approximately 10 feet below the ground surface. Nitrate concentrations in the other wells ranged from 0.12 to 9.45 mg/l (N), with concentrations in seven of the 14 wells less than 1.0 mg/l (N).

In all, 45 of the 52 wells sampled in the Kidder/Marstonmoor Plain aquifer system in 1994/1996, 87 percent, were resampled in 1999. Figure 6 compares the percentages of nitrate detections in the Kidder/Marstonmoor Plain aquifer system for the years 1994/1996 and 1999. As shown in Figure 6, the overall percentage of wells with nitrate detections decreased by slightly over 30 percent from 1994/1996 to 1999. The largest decrease in detections was in wells with concentrations less than 1.0 mg/l (N). This is also true when comparing only the wells sampled in both sampling periods. However, when comparing all wells sampled each year or only the wells sampled in both years, there was a slight increase in the percentage of wells with nitrate concentrations greater than or equal to the 10 mg/l (N) MCL. In 1994/1996, there was one well with a nitrate concentration above the MCL; in 1999, there were three wells in that category, including two wells that previously contained intermediate-concentration detections. Table 6 lists all 45 wells sampled in both years, along with the nitrate concentrations detected in each well.

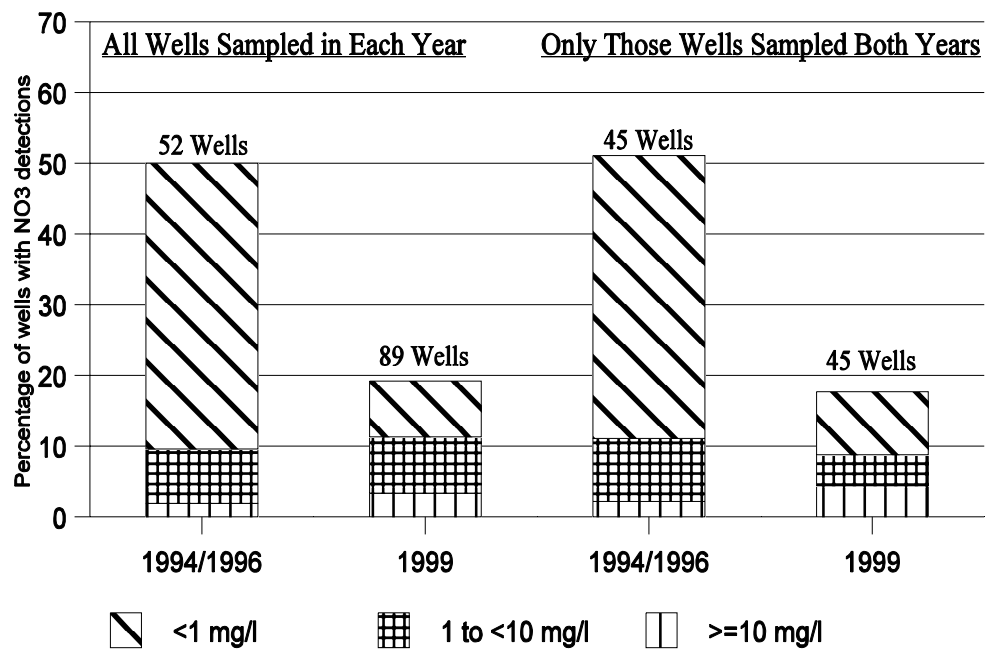


FIGURE 6. Graph of nitrate detections in the Kidder/Marstonmoor Plain aquifer for the years 1994/1996 and 1999

TABLE 6
Summary of Nitrate Concentrations
in the Wells in the Kidder/Marstonmoor Plain Aquifer
Sampled in Both 1994 or 1996 and 1999
 In milligrams per liter [mg/l] (N)

Well ID #	Type of Well	1994/1996	1999
1. 138 071 20 BDD	Stock	0.06	ND
2. 138 072 01 AAA2	Monitoring	ND	ND
3. 138 072 02 CBA	Domestic	ND	ND
4. 138 072 03 AAA4	Monitoring	0.06	0.12
5. 138 072 17 AAA2	Monitoring	ND	ND
6. 139 070 01 DDD	Domestic	ND	ND
7. 139 070 03 DDD	Domestic	ND	ND
8. 139 070 04 DDA2	Monitoring	0.08	ND
9. 139 070 05 DDC2	Monitoring	0.06	ND
10. 139 070 10 DDB	Domestic	0.07	ND
11. 139 070 11 AAA2	Domestic	0.06	ND
12. 139 071 03 BBB2	Monitoring	0.05	ND
13. 139 071 04 CCC	Monitoring	0.09	ND
14. 139 071 05 CCA	Domestic	0.07	ND
15. 139 071 09 AAA	Domestic	0.07	ND
16. 139 071 10 CDD	Domestic	ND	ND
17. 139 071 11 AAA	Monitoring	0.06	ND
18. 139 071 12 CCC	Domestic	ND	ND
19. 139 071 14 CBB	Domestic	1.15	1.48
20. 139 071 17 BBB2	Monitoring	0.08	ND
21. 139 071 18 ABA	Watering lawn/garden	0.94	2.24
22. 139 072 21 BBB2	Monitoring	ND	ND
23. 139 072 34 BBB3	Monitoring	ND	ND
24. 140 070 19AAA	Stock	ND	ND
25. 140 070 30 CCC	Monitoring	0.07	ND

TABLE 6 (continued)
Summary of Nitrate Concentrations
in the Wells in the Kidder/Marstonmoor Plain Aquifer
Sampled in Both 1994 or 1996 and 1999

In milligrams per liter [mg/l] (N)

Well ID #	Type of Well	1994/1996	1999
26. 140 071 14 BBB1	Monitoring	ND	ND
27. 140 071 17 AAA2	Monitoring	ND	ND
28. 140 071 19 DDD3	Monitoring	1.46	11.9
29. 140 071 24 DDD3	Monitoring	1.80	10.5
30. 140 071 26 CCC2	Monitoring	0.08	ND
31. 140 071 28 DAA2	Monitoring	ND	ND
32. 140 071 31 AAA2	Monitoring	ND	ND
33. 140 071 32 DAA	Stock	ND	ND
34. 140 071 33 CBB2	Monitoring	ND	ND
35. 141 070 02 CDD	Domestic	0.19	ND
36. 141 070 13 CDD2	Monitoring	0.96	0.59
37. 141 070 14 DCC2	Monitoring	2.44	0.68
38. 142 070 04 AAA	Domestic	0.06	ND
39. 142 070 11 DCC	Domestic	ND	ND
40. 142 070 13 ACC	Domestic	ND	ND
41. 142 070 14 BCC	Domestic	ND	ND
42. 142 070 16 BAD3	Monitoring	ND	ND
43. 142 070 18 ABB	Domestic	0.02	ND
44. 142 070 20 BBB	Monitoring	ND	ND
45. 142 070 28 DAA2	Monitoring	13.7	0.40

ND = Not Detected

Milnor Channel Aquifer

Sixty-four samples were collected from 61 wells in the Milnor Channel aquifer. The water in the aquifer is predominantly a calcium bicarbonate type. Samples collected were high in iron and manganese. Nearly one-half of the wells sampled had sulfate concentrations that exceeded the 250 mg/l recommended limit, and two-thirds of the wells exceeded the 500 mg/l recommended sodium limit. Median hardness was high at 424 mg/l.

Pesticides were detected in six of the 61 wells sampled in the Milnor Channel aquifer in 1999, or approximately 10 percent of the wells sampled. Dicamba initially was detected in well 13205336BBC at a concentration of 0.13 $\mu\text{g/l}$, or 0.065 percent of the 200 $\mu\text{g/l}$ HAL. The follow-up sample did not contain any pesticides. This is a 1.25-inch-diameter monitoring well constructed of PVC casing and screened from 38 to 41 feet. The well is located in a road ditch and within 100 feet of row crops and surface water.

Dicamba also was detected in both a regular and a duplicate sample collected from well 13205409CBC at concentrations of 0.06 and 0.08 $\mu\text{g/l}$, respectively. No pesticides were detected in a follow-up sample collected four months later. This is a 4-inch-diameter domestic well constructed of PVC and screened from 18 to 22 feet. This well is located in a city within one-eighth mile of surface water.

Three wells in the Milnor Channel aquifer had initial detections of picloram. Well 13105136BBC had a picloram concentration of 0.16 $\mu\text{g/l}$ in the initial sample collected. Picloram also was detected at a concentration of 0.13 $\mu\text{g/l}$ in a follow-up sample collected four months later. This is a domestic well located in a farmyard within one-eighth of a mile of a septic system and feedlot. The well is screened from 22 to 32 feet and the water level in the well at the time it was constructed was 10 feet below the ground surface. Picloram also was detected in the well when it was sampled in 1994 and in 1995.

Picloram also was detected in a second domestic well, 13005007AAA, at a concentration of 0.56 $\mu\text{g/l}$, or 0.112 percent of the MCL. The well is screened from 40 to 50 feet, and the water level in the well at the time it was constructed was 10 feet below the ground surface. The well is located near a septic system and within one-eighth mile of row crops and surface water.

The third well with a picloram detection, 13005211ADA, had a concentration of $0.27 \mu\text{g/l}$ in the initial sample collected. Picloram also was detected in a follow-up sample at a concentration of $0.20 \mu\text{g/l}$. These figures are 0.054 and 0.04 percent of the MCL, respectively. The well is a 2-inch-diameter monitoring well constructed of PVC and screened from 25 to 30 feet. The water level in the well was less than 5 feet below the ground surface at the time it was sampled. The well is located on the edge of a farmyard within 100 feet of a septic system and surface water.

Pentachlorophenol was detected in well 13005010CCC at a concentration of $0.05 \mu\text{g/l}$, or 5.0 percent of the MCL. No pesticides were detected in a follow-up sample collected from the well. This is a 2-inch-diameter monitoring well constructed of PVC, screened from 98 to 103 feet and with a static water level less than 5 feet below ground surface. The well was located within 100 feet of row crops and surface water.

In 1994, three of 32 wells sampled, approximately 9 percent, had detections of pesticides. Two of the wells also were sampled in 1999; one well, 13105136BBC, had a pesticide detected again in 1999 and is discussed in the preceding section.

Eleven wells, or 18 percent of the wells sampled in the Milnor channel aquifer, contained detectable nitrate concentrations. All of the concentrations were below the 10 mg/l (N) MCL . As shown in Figure 7, the overall percentage of wells with nitrate detections decreased slightly from 1994 to 1999; the major change was a decrease in the percentage of wells with intermediate-concentration detections and corresponding increase in low-concentration detections. Almost twice as many wells were sampled in 1999 as were sampled in 1994. When comparing only the 28 wells sampled in both years, the overall percentage of wells with nitrate detections and the percentages of wells with low- and high-concentration detections did not change. There were no nitrate detections at or above the MCL either year. Table 7 lists all 28 wells sampled in both 1994 and 1999, along with the nitrate concentrations detected in each well.

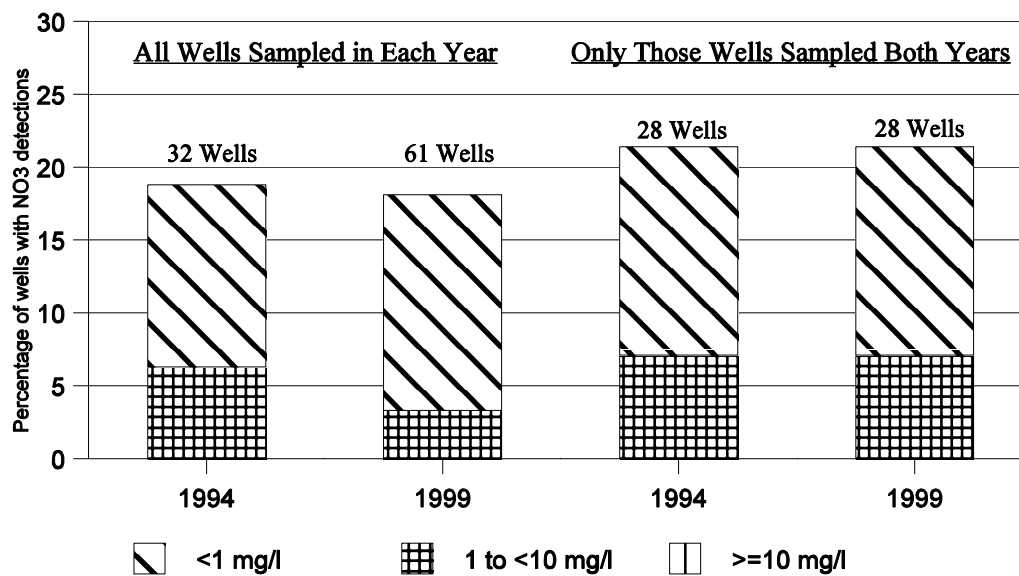


Figure 7. Graph of nitrate detections in the Milnor Channel aquifer for the years 1994 and 1999

TABLE 7
Summary of Nitrate Concentrations
in the Wells in the Milnor Channel Aquifer Sampled in Both 1994 and 1999
 In milligrams per liter [mg/l] (N)

Well ID #	Type of Well	1993	1998
1. 129 050 22 AADC	Domestic	ND	ND
2. 129 050 26 DDC	Domestic	ND	ND
3. 130 050 03 CAB	Domestic	0.26	ND
4. 130 050 07 AAA	Domestic	0.03	ND
5. 130 051 06 CC	Stock	ND	ND
6. 130 051 08 BBB	Domestic	ND	ND
7. 130 051 09 ABD	Domestic	0.30	0.22
8. 130 052 02 DDD	Domestic	0.16	0.26
9. 130 052 08 DAD	Domestic	ND	ND
10. 130 052 17 BB	Domestic	ND	ND
11. 130 053 11 DDD	Domestic	ND	ND
12. 131 051 24 CBA	Domestic	ND	0.06
13. 131 051 36 BBC	Domestic	ND	ND
14. 131 053 02 CCB	Domestic	0.02	ND
15. 131 053 05 DAD	Domestic	ND	ND
16. 131 053 07 DAA	Domestic	0.03	ND
17. 131 053 10 DDC	Domestic	0.02	ND
18. 131 053 13 BCC	Domestic	ND	ND
19. 131 053 14 CAD	Domestic	2.16	3.16
20. 131 053 23 BBB	Domestic	0.02	Preserved w/HNO3
21. 132 053 23 CCD	Stock	ND	ND
22. 132 053 26 BBB	Domestic	0.04	0.30
23. 132 054 08 AAD	Domestic	0.08	ND
24. 132 054 09 CBC	Domestic	ND	ND
25. 132 055 01 CDD	Domestic	ND	ND
26. 133 054 34 DCC	Domestic	ND	ND
27. 133 055 22 ABA	Domestic	5.63	3.75
28. 133 055 25 AAD	Domestic	ND	ND

ND = Not Detected

Sheyenne Delta Aquifer

A total of 89 samples were collected from 69 wells in the Sheyenne Delta aquifer. The water from the aquifer is primarily a calcium bicarbonate type water, with calcium the dominant cation in all but five of the samples. Nearly one-half of the samples collected had TDS above the recommended limit of 500 mg/l. The water is generally high in iron and manganese, low in sodium and within the recommended limit for sulfate. Average hardness was very high at 481 mg/l as CaCO_3 .

In 1999, the Sheyenne Delta aquifer had 17 wells, approximately 25 percent, with detectable levels of pesticides. All wells were either domestic or monitoring wells, with diameters ranging from 1.25 inches to 4 inches and well depths ranging from 11.9 to 70 feet. The water table was very high in the Sheyenne Delta aquifer with water levels ranging from 1.78 to 20 feet below the ground surface and averaging approximately 5.5 feet below the ground surface.

Picloram was the most frequently detected pesticide with initial concentrations in eight wells ranging from 0.07 to 1.26 $\mu\text{g/l}$, or 0.014 to 0.252 percent of the 500 $\mu\text{g/l}$ MCL. Five of the wells -- 13305311BBB2, 13405304AABAAB1, 13405314DCCCCC1, 13605124DADDAB1 and 13605229DDD -- were monitoring wells constructed of PVC with diameters of 1.25 or 2 inches. The depth of the wells ranged from 12.5 to 70 feet, and the top of the screen ranged from approximately 5.5 to 67 feet below ground surface. All five wells were located in a pasture/roadside setting, and three were near surface water. The remaining three wells with picloram detections -- 13305118ABB, 13405120AAA and 13605210ADD2 -- are private wells used for watering livestock. One well was 41 feet deep and another was 48 feet deep with approximate water levels of 8 and 12 feet below the ground surface, respectively. Information about the well construction of the third well was not available; however, a domestic well located on the same farm is 48 feet deep. The primary setting for all three wells is in a farmyard, and all three wells are near a feedlot and septic system. Three of the wells with initial picloram detections -- 13305118ABB, 13405120AAA and 13605124DADDAB1 -- also had picloram detected in follow-up samples at concentrations ranging from 0.10 to 0.26 $\mu\text{g/l}$.

Three of the wells with picloram detections also had detections of other pesticides. Well 13305311BBB2 had a detected concentration of pentachlorophenol at 0.12 $\mu\text{g/l}$, or 12 percent of

the MCL set at 1.0 $\mu\text{g/l}$, and of bromoxynil at 0.027 $\mu\text{g/l}$. There is no MCL or HAL for bromoxynil. No pesticides were detected in a follow-up sample collected from the well.

In addition to picloram, the initial sample collected from well 13405314DCCCCC1 also had concentrations of DDT (0.02 $\mu\text{g/l}$), endrin (0.046 $\mu\text{g/l}$ or 2.3 percent of the MCL), 2,4-D (0.28 $\mu\text{g/l}$, 0.4 percent of the MCL), pentachlorophenol (0.04 $\mu\text{g/l}$, 4.0 percent of the MCL), 2,4,5-T (0.1 $\mu\text{g/l}$, 0.143 percent of the HAL), dichlorprop (0.49 $\mu\text{g/l}$) and bentazon (0.27 $\mu\text{g/l}$, 1.35 percent of the HAL) detected. There is no MCL or HAL for DDT or dichlorprop. No pesticides were detected in a follow-up sample from the well.

In addition to picloram, well 13605229DDD had detections of 2,4,5-T and pentachlorophenol in the initial sample collected. The concentration of 2,4,5-T detected was 0.05 $\mu\text{g/l}$, or 0.071 percent of the HAL, and of pentachlorophenol, 0.23 $\mu\text{g/l}$, or 23 percent of the MCL.

In addition to the three wells mentioned above, pentachlorophenol also was detected in four other wells in the Sheyenne Delta aquifer -- 13405312BBB2, 13505210ACA2, 13505227CCC2 and 13505233DAAAAA1. All four wells are monitoring wells with well depths ranging from 11.9 to 61 feet. The water level in all four wells was less than 5 feet below the surface of the ground. Well diameters were from 1.25 to 4 inches; three of the wells were constructed of PVC and one of iron. All four wells were located along a roadside and in either a pasture or field setting. Three of the wells also were near surface water. Concentrations of pentachlorophenol in the samples ranged from 0.07 to 12 $\mu\text{g/l}$, or 7 percent to 12 percent of the MCL. Pentachlorophenol was the only pesticide detected in all four wells, and no pesticides were detected in follow-up samples from any of the wells.

Well 13505119DAAAAA1 had detections of DDT (0.036 $\mu\text{g/l}$), endrin (0.075 $\mu\text{g/l}$ or 3.75 percent of the MCL, set at 2.0 $\mu\text{g/l}$), endrin ketone (0.016 $\mu\text{g/l}$, 0.8 percent of the MCL) and atrazine (0.807 $\mu\text{g/l}$ or 26.9 percent of the MCL, set at 3.0 $\mu\text{g/l}$) in the initial sample collected. The well is a 2-inch-diameter monitoring well constructed of PVC. The well is screened from 4.5 to 9.6 feet, and the water level was just below the surface of the ground. The well is located along the roadside and near a pasture and surface water. No pesticides were detected in a follow-up sample collected from the well.

Diclofop-methyl was detected in the initial sample collected from well 13505134BCCCCB1 at a concentration of 0.35 $\mu\text{g/l}$. There is no MCL or HAL for diclofop-methyl. The well is a 2-inch-diameter PVC-cased monitoring well. The well is screened from 4.72 to 9.72 feet, and the water level was approximately 4 feet below ground surface. The well is located in a field/roadside setting near a small-grains crop. No pesticides were detected in a follow-up sample from the well.

Endosulfan I was detected in 13505204BDBBBD at a concentration of 0.01 $\mu\text{g/l}$. There is no MCL or HAL for endosulfan I. The well is a 2-inch-diameter PVC-cased monitoring well screened from 23 to 28 feet. The water level was approximately 18 feet below ground surface. The well is located in a roadside/field setting near row crops. No pesticides were detected in a follow-up sample collected from the well.

DDT and endosulfan sulfate were detected in a sample from well 13605228ABBBBB, both at a concentration of 0.01 $\mu\text{g/l}$. There is no MCL or HAL for either pesticide. This well is a 2-inch-diameter, PVC-cased monitoring well screened from 9.9 to 14.9 feet. The water level in the well was less than 5 feet below the surface of the ground. The well is located in a field/roadside setting near hay land and row crops. No pesticides were detected in a follow-up sample collected from the well.

Malathion was detected in both the regular and a duplicate sample collected from well 13705228CAA at concentrations of 0.379 and 0.46 $\mu\text{g/l}$, respectively, or 0.19 percent and 0.23 percent of the 200 $\mu\text{g/l}$ HAL. The follow-up sample collected approximately four months later did not contain any pesticides. This well is a 4-inch-diameter domestic well providing water to a grain elevator. The well is screened from 60 to 70 feet, and the water level in the well at the time it was installed was approximately 25 feet below ground surface. The well is located within one-eighth mile of a septic system, surface water and row crops. No pesticides were detected in the well during follow-up confirmation sampling.

In 1994, 16 of the 60 wells sampled, approximately 27 percent, had detections of pesticides. Twelve of the 16 wells also were sampled in 1999; four wells had pesticide detections in both years. Table 8 lists the four wells with a summary of all pesticides detected in them.

TABLE 8
Summary of Wells in the Sheyenne Delta Aquifer
With Pesticide Detections Both Prior to and in 1999
 In micrograms per liter ($\mu\text{g/l}$)

LOCATION/ WELL ID NUM.	DATE	CHEMICAL DETECTED	DETECTED CONC. (Ug/l)	% of HAL or MCL	SAMPLE TYPE
13405120AAA	06/15/94	Picloram	0.270	0.054	R
13405120AAA	06/15/94	Picloram	0.250	0.050	D
13405120AAA	05/09/95	None			R
13405120AAA	05/05/99	Picloram	0.250	0.050	R
13405120AAA	09/22/99	Picloram	0.220	0.044	R
13505119DAAAAA1	06/01/94	Atrazine	0.500	16.667	R
13505119DAAAAA1	06/01/94	Atrazine	0.600	20.000	D
13505119DAAAAA1	05/10/95	Atrazine	1.210	40.333	R
13505119DAAAAA1	05/10/95	Atrazine	1.360	45.333	D
13505119DAAAAA1	11/01/95	Picloram	0.100	0.020	R
13505119DAAAAA1	04/15/99	DDT	0.036	No MCL or HAL	R
13505119DAAAAA1	04/15/99	Endrin	0.075	3.750	R
13505119DAAAAA1	04/15/99	Endrin Ketone	0.016	0.800	R
13505119DAAAAA1	04/15/99	Atrazine	0.807	26.900	R
13505119DAAAAA1	09/21/99	None			R
13605124DADDAB1	06/01/94	Picloram	2.35	0.470	R
13605124DADDAB1	05/10/95	Picloram	2.12	0.424	R
13605124DADDAB1	04/13/99	Picloram	0.390	0.078	R
13605124DADDAB1	10/26/00	Picloram	0.260	0.052	R
13605228ABBBBB	11/17/93	None			R
13605228ABBBBB	03/15/94	Picloram	0.140	0.028	R
13605228ABBBBB	04/19/94	Picloram	0.320	0.064	R
13605228ABBBBB	05/25/94	Picloram	0.370	0.074	R
13605228ABBBBB	05/25/94	Picloram	0.480	0.096	D
13605228ABBBBB	07/14/94	Picloram	1.020	0.204	R
13605228ABBBBB	04/14/99	DDT	0.010	No MCL or	R
13605228ABBBBB	04/14/99	Endosulfan	0.010	No MCL or	R
13605228ABBBBB	09/20/99	None			R

R = Regular Sample; D = Duplicate Sample.

Eighteen wells, or 26 percent of the wells sampled in the Sheyenne Delta aquifer, contained detectable nitrate concentrations. Two-thirds of the nitrate detections were less than 1.0 mg/l. Only one well had a concentration greater than or equal to the MCL of 10 mg/l (N). This well, 13505317AAC, is a 4-inch-diameter domestic well screened from 20 to 30 feet below the ground surface. The well is located in a farmyard within 100 feet of a septic system and within one-eighth mile of row crops and surface water. This well also was sampled in 1994 and in 1995; on both previous occasions, the nitrate concentration in the well exceeded the MCL.

Figure 8 compares percentages of wells with nitrate concentrations in the Sheyenne Delta aquifer for the years 1994 and 1999. As shown in Figure 8, the overall percentage of wells with nitrate detections decreased from 1994 to 1999, as did the percentages of wells with high and intermediate concentrations. Low-concentration detections increased slightly – less than 1 percent. When comparing only the wells sampled both years, this general pattern also is observed; however, the percentage of wells with low nitrate detections was identical for both years. Of the two wells with nitrate detections exceeding the 10 mg/l MCL in 1994, one decreased to below detectable levels in 1999, and the concentration in the other well, discussed above, increased from 10.8 to 17.4 mg/l. Table 9 lists all 45 wells sampled in the Sheyenne Delta aquifer in both 1994 and 1999, along with the nitrate concentrations detected in the wells. Some wells also were sampled in 1995; these results also are included in the table.

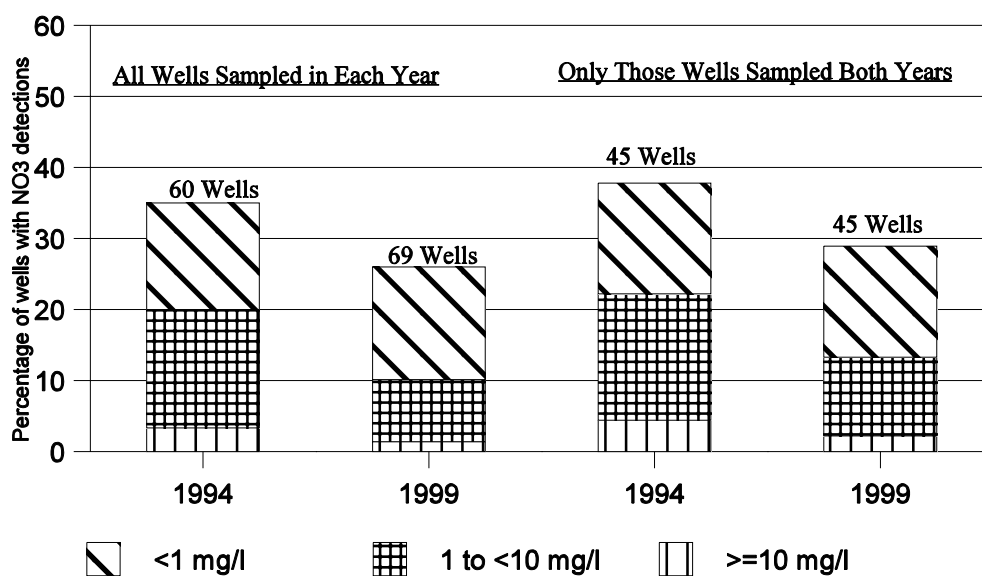


Figure 8. Graph of nitrate detections in the Sheyenne Delta aquifer for the years 1994 and 1999

TABLE 9
Summary of Nitrate Concentrations
in the Wells in the Sheyenne Delta Aquifer Sampled in Both 1994 and 1999

In milligrams per liter [mg/l] (N)

Well ID #	Type of Well	1994	1995	1999
1. 133 051 06 DDA	Domestic	ND	N/A	ND
2. 133 051 09 BDD	Domestic	ND	N/A	ND
3. 133 051 18 ABB	Stock	1.21	N/A	0.82
4. 133 051 30 AAC	Domestic	ND	N/A	0.26
5. 133 051 32 BCB	Domestic	ND	N/A	ND
6. 133 053 17 ADD	Domestic	0.02	N/A	ND
7. 133 054 01 ABCCBD	Monitoring	0.02	N/A	ND
8. 134 051 18 CCC	Lawn Watering	ND	N/A	ND
9. 134 051 20 AAA	Stock	1.86	2.37	1.37
10. 134 051 32 BBB	Domestic	ND	0.03	ND
11. 134 052 02 ABC	Stock	ND	N/A	ND
12. 134 052 21 CDDCDB1	Monitoring	ND	N/A	ND
13. 134 052 36 CCC	Domestic	2.46	N/A	0.98
14. 134 053 04 AAABAAB1	Monitoring	0.022	N/A	ND
15. 134 054 02 DDDDDDD1	Monitoring	6.57	N/A	9.44
16. 134 054 21 AAA	Stock	ND	0.09	ND
17. 135 050 18 DCD	Domestic	ND	N/A	ND
18. 135 051 10 CCB BBB1	Monitoring	0.129	N/A	0.11
19. 135 051 19 DAAAAA1	Monitoring	0.02	0.05	ND
20. 135 051 34 BCCCCB1	Monitoring	ND	N/A	ND
21. 135 052 04 BDBBBBD	Monitoring	0.08	N/A	ND
22. 135 052 25 AAABAA	Monitoring	0.017	N/A	ND
23. 135 052 33 DAAAAA1	Monitoring	ND	N/A	ND
24. 135 053 16 BBAB	Monitoring	0.067	N/A	ND
25. 135 053 17 AAC	Domestic	10.8	12.1	17.4

TABLE 9 (continued)
Summary of Nitrate Concentrations
in the Wells in the Sheyenne Delta Aquifer Sampled in Both 1994 and 1999

In milligrams per liter [mg/l] (N)

Well ID #	Type of Well	1994	1995	1999
26. 135 053 21 BBAB2	Monitoring	19.8	N/A	ND
27. 135 053 28 BBBADB1	Monitoring	ND	N/A	ND
28. 135 054 16 ACDDDD1	Monitoring	ND	N/A	ND
29. 135 054 29 DAAAAA	Monitoring	ND	N/A	ND
30. 136 051 10 CCD	Domestic	6.65	N/A	3.66
31. 136 051 19 DCD	Domestic	1.44	N/A	3.77
32. 136 051 24 DADDAB1	Monitoring	0.45	1.20	0.09
33. 136 051 25 BCCCCC1	Monitoring	ND	N/A	ND
34. 136 051 31 ADBDBA1	Monitoring	ND	N/A	ND
35. 136 051 32 BCD	Domestic	ND	0.08	ND
36. 136 051 32 CCCCCC1	Monitoring	0.01	N/A	ND
37. 136 051 36 AA	Domestic	0.02	N/A	ND
38. 136 052 09 ADDDDDD1	Monitoring	ND	N/A	ND
39. 136 052 10 ADD	Stock	N/A	N/A	ND
40. 136 052 14 CBBCCD1	Monitoring	0.07	N/A	ND
41. 136 052 22 ABB	Domestic	1.33	N/A	ND
42. 136 052 28 ABBBBBB	Monitoring	1.69	N/A	4.90
43. 136 053 26 ABAAAA1	Monitoring	0.364	N/A	0.63
44. 137 052 17 DDC	Domestic	ND	N/A	0.18
45. 137 052 28 CAA	Domestic	ND	N/A	ND

ND = Not Detected; N/A = Not Applicable

Well Construction / Water Quality Relationships

Relationships between pesticide and nitrate detections and most well characteristics are difficult to define from these sample results. This is especially true for pesticides because of the very low overall percentage of detections in relation to the total sample population. When trying to relate well-construction characteristics to a small subset population of detections, percentages change rapidly and confidence levels are low. See Table 10 for a summary of statistics on well construction related to pesticide and nitrate plus nitrite detections in this survey. Appendix D contains these summary statistics for each aquifer.

In general, the depth of the well, the depth to the top of the screened interval and the distance from the water table to the top of the screen seemed to show a relationship to pesticide and nitrate detections. The overall percentages of pesticide and nitrate detections generally decreased with increasing well depth, with increasing depth to the top of the screened interval, and as the distance from the water table to the top of the screen increased. This general relationship also was observed for the percentages of high, intermediate and low nitrate concentrations; however, this relationship was not evident for all the various concentration intervals in all instances. These will be discussed individually in the following paragraphs. The best correlation was between nitrate detections and the depth to the top of the screened interval. The above findings are consistent with the results of the 1994 study, in which all three of the depth-related characteristics seemed to correlate to pesticide and nitrate plus nitrite detections. The greatest percentages of both pesticide and nitrate detections were associated with livestock wells, although few wells were sampled in that category. In 1994, the greatest percentage of pesticide detections was in livestock wells, while the greatest percentage of nitrate detections occurred in monitoring wells. The casing material and diameter of the well could not be used to show a relationship to either nitrate or pesticide detections. At least 90 percent of all wells sampled were PVC-cased monitoring wells less than 6 inches in diameter, thus making comparisons difficult.

More detailed relationships between well characteristics and nitrate are generally easier to define because of the much higher percentage of nitrate detections. The relationship between the intervals of nitrate concentrations and various well characteristics is shown graphically in Figures 9 through 12. The number of wells sampled in each category is shown at the top of the columns in the graphs.

TABLE 10
Pesticide and Nitrate plus Nitrite Detections
Related to Well Construction
For All Aquifers Sampled in 1999

NUMBER OF DETECTIONS		#	PERCENT
Wells with only pesticide detections	:	29	10.0 %
Wells with only nitrate detections	:	45	15.5 %
Wells with pesticide & nitrate detections	:	14	4.8 %
Wells with nitrate > 10 mg/L	:	5	1.7 %
Total number of wells in sample population		:	290

AQUIFER	#	%	#	%	#	%
			PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
GALESBURG/PAGE :	46	15.9	7	15.2	7	15.2
HANKINSON :	25	8.6	8	32.0	6	24.0
KIDDER/MARSTONMOOR :	89	30.7	5	5.6	17	19.1
MILNOR CHANNEL :	61	21.0	6	9.8	11	18.0
SHEYENNE DELTA :	69	23.8	17	24.6	18	26.1

DEPTH OF WELLS	#	%	#	%	#	%
			PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 20 Ft. :	22	7.6	7	31.8	6	27.3
20 - 50 Ft. :	123	42.4	19	15.4	34	27.6
> 50 Ft. :	144	49.7	16	11.1	18	12.5
Unknown :	1	0.3	1	100.0	1	100.0

DIAMETER OF WELL	#	%	#	%	#	%
			PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 6 in. :	285	98.3	41	14.4	56	19.6
6 - 18 in. :	2	0.7	0	0.0	1	50.0
> 18 in. :	2	0.7	1	50.0	1	50.0
Unknown :	1	0.3	1	100.0	1	100.0

CASING MATERIAL	#	%	#	%	#	%
			PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Plastic(PVC or ABS) :	261	90.0	36	13.8	52	19.9
Concrete/Brick/Stone :	0	0.0	0	*****	0	*****
Metallic :	27	9.3	6	22.2	6	22.2
Other :	2	0.7	1	50.0	1	50.0

DEPTH TO TOP OF SCREENED INTERVAL	#	%	#	%	#	%
			PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 20 Ft. :	35	12.1	10	28.6	12	34.3
20 - 50 Ft. :	137	47.2	19	13.9	32	23.4
> 50 Ft. :	112	38.6	13	11.6	13	11.6
Unknown :	6	2.1	1	16.7	2	33.3

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	%	#	%	#	%
			PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 10 Ft. :	38	13.1	10	26.3	14	36.8
10 - 30 Ft. :	112	38.6	14	12.5	33	29.5
> 30 Ft. :	125	43.1	16	12.8	10	8.0
Unknown :	15	5.2	3	20.0	23	20.0

TYPE OF WELL	#	%	#	%	#	%
			PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Monitoring :	188	64.8	27	14.4	36	19.1
Private/Domestic :	84	29.0	11	13.1	17	20.2
Livestock :	14	4.8	5	35.7	4	28.6
Public Supply :	2	0.7	0	0.0	1	50.0
Irrigation :	1	0.3	0	0.0	1	100.0
Other :	1	0.3	0	0.0	0	0.0

is the number of wells or detections in that category.
 % is the perecentage of wells or detections in that category.

Figure 9 depicts the percentage of nitrate detections versus well depth for various detection concentration intervals. The overall percentages of nitrate detections were almost identical in wells that were less than 20 feet deep and in wells that were 20 to 50 deep, which may be a reflection of the much greater number of wells sampled in the deeper category. In general, the percentages of low-, intermediate- and high-concentration intervals decreased with increasing well depth, except for the percentage of low-concentration detections, which was slightly greater in wells 20 to 50 deep than in the shallower wells. Again, this may reflect the greater number of wells sampled in the intermediate depth category. There were no nitrate detections at or above the MCL in wells over 50 feet deep.

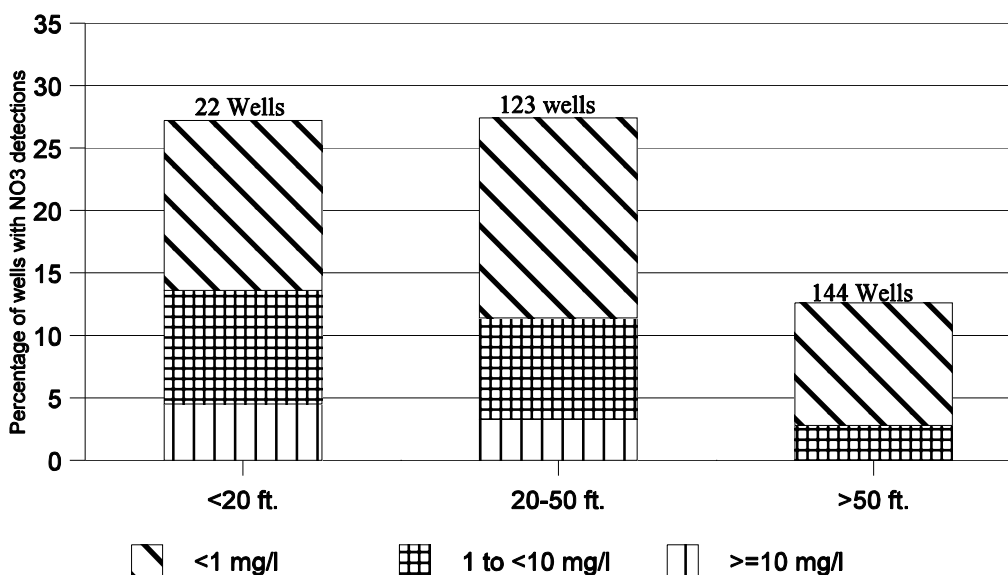


Figure 9. Graph of nitrate detections vs. well depth

Figure 10 depicts the percentage of nitrate detections versus the depth to the top of the screened interval. The greatest percentage of nitrate detections occurred in wells in which the top of the screened interval was less than 20 feet below ground surface. The overall percentage of nitrate detections decreased with increasing depth to the top of the screened interval, as did the percentages of the high-, intermediate- and low-concentration detections. There were no nitrate detections at or above the MCL in wells in which the depth to the top of the screened interval was greater than 50 feet.

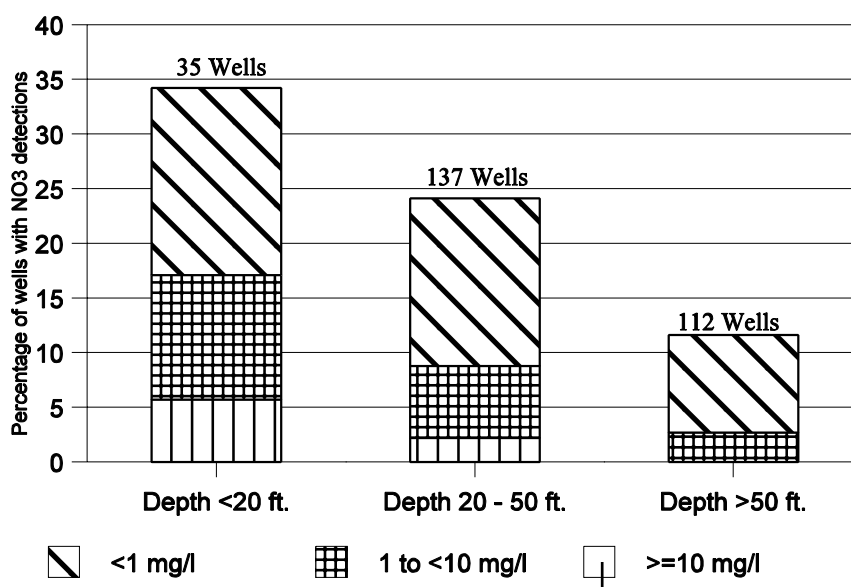


FIGURE 10. Graph of nitrate detections vs. depth to top of screened interval

As shown in Figure 11, approximately 37 percent of wells in which the distance from the water table to the top of the screen was less than 10 feet contained nitrate. The overall percentage of nitrate detections decreased with increasing distance from the water table to the top of the screen; however, this did not hold true for all concentration intervals. The percentage of low-concentration detections was slightly greater in the 10- to 30-feet distance category than in the less-than-10-feet category, while the percentage of medium-concentration detections was essentially the same in both distance intervals. In wells in which the distance from the water table to the top of the screen was more than 30 feet, there was one well (0.8 percent) with an intermediate nitrate detection and no nitrate detections at or above the MCL.

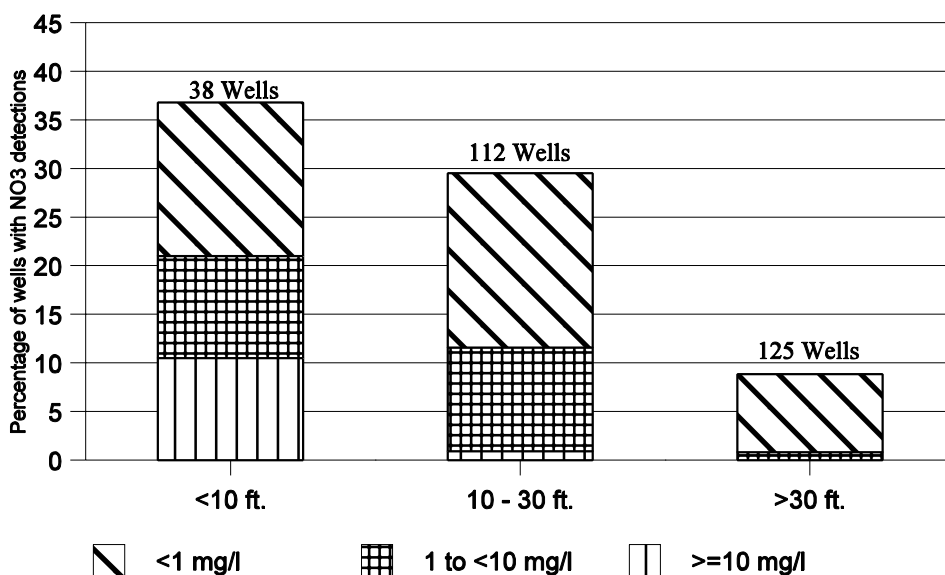


FIGURE 11. Graph of nitrate detections vs. distance from water table to the top of the screen

Figure 12 depicts the percentage of nitrate detections versus well type for various concentration intervals. Irrigation and public supply wells are not depicted on the graph because only two of each of those wells were sampled. Although 65 percent of the wells sampled were monitoring wells, they had the lowest overall percentage of nitrate detections, at approximately 19 percent. The overall percentage of nitrate detections was almost the same in both monitoring and private domestic wells. Livestock wells had the greatest overall percentage of nitrate detections, as well as the greatest percentages of intermediate- and high-concentration detections; however, few livestock wells were sampled in comparison to monitoring and domestic wells, making comparisons less precise. The smallest percentages of intermediate and high nitrate concentrations were found in monitoring wells, which is consistent with the results for the first five-year monitoring cycle, 1992-1996 (Bartelson and Gunnerson, 2000).

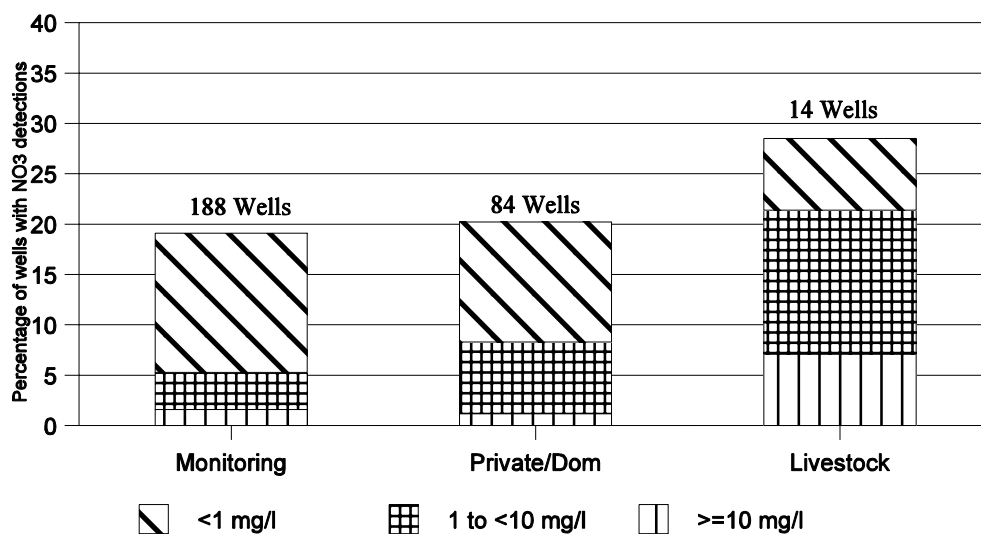


Figure 12. Graph of nitrate detections vs. type of well

Low-concentration detections of nitrate generally correspond less closely to the various well-construction factors than higher concentrations. Higher concentration detections are more likely to result from point sources of pollution, rather than non-point sources, which may explain the relationship between high nitrate concentration detections and well construction. Detections resulting from non-point sources may likely occur regardless of well construction characteristics because of the widespread nature of non-point nitrate contamination. This study, however, did not identify whether any individual detection is caused by point or non-point sources.

Site-Inventory Data / Water Quality Relationships

Based upon the information collected as part of this survey, it is also difficult to relate pesticide detections to site characteristics or land use. The total number of pesticide detections is too low to arrive at relationships with any degree of confidence. It also was attempted to relate the distance from the well of certain site characteristics to pesticide and nitrate detections. This was also largely inconclusive for pesticide detections because of the small number of detections related to each site characteristic. Refer to Table 11 for a summary of statistics on pesticide and nitrate detections related to site-inventory characteristics. Appendix D contains these summary statistics for each aquifer.

TABLE 11
Pesticide and Nitrate Plus Nitrite Detections
Related to Site-Inventory Data
For All Aquifers Sampled in 1999

NUMBER OF DETECTIONS	#	PERCENT
Wells with only pesticide detections	: 29	10.0 %
Wells with only nitrate detections	: 45	15.5 %
Wells with pesticide & nitrate detections	: 14	4.8 %
Wells with nitrate > 10 mg/L	: 5	1.7 %

Total number of wells in sample population : 290

AQUIFER	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
GALESBURG/PAGE	: 46	15.9	7	15.2	7	15.2
HANKINSON	: 25	8.6	8	32.0	6	24.0
KIDDER/MARSTONMOOR	: 89	30.7	5	5.6	17	19.1
MILNOR CHANNEL	: 61	21.0	6	9.8	11	18.0
SHEYENNE DELTA	: 69	23.8	17	24.6	18	26.1

GENERAL SETTING	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Farm Yard	: 91	31.4	13	14.3	22	24.2
Field	: 144	49.7	22	15.3	29	20.1
Pasture	: 62	21.4	14	22.6	14	22.6
C.R.P.	: 14	4.8	0	0.0	3	21.4
Roadside	: 168	57.9	24	14.3	35	20.8
Town	: 6	2.1	3	50.0	0	0.0

NEARBY FACTORS OF POSSIBLE INFLUENCE	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Near Irrigation	: 65	22.4	5	7.7	19	29.2
Near Feed Lot	: 56	19.3	7	12.5	15	26.8
Near Disposal Area	: 3	1.0	1	33.3	1	33.3
Near Septic System	: 113	39.0	18	15.9	25	22.1
Near Surface Water	: 130	44.8	28	21.5	28	21.5
Well in Depression	: 12	4.1	2	16.7	3	25.0
Near Chemical Usage	: 45	15.5	12	26.7	12	26.7
Other	: 6	2.1	2	33.3	2	33.3

NEAR IRRIGATION	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 6	2.1	1	16.7	2	33.3
100 ft. - 1/8 mile	: 59	20.3	4	6.8	17	28.8

NEAR A FEED LOT	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 18	6.2	4	22.2	4	22.2
100 ft. - 1/8 mile	: 38	13.1	3	7.9	11	28.9

NEAR DISPOSAL AREA	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 1	0.3	1	100.0	1	100.0
100 ft. - 1/8 mile	: 2	0.7	0	0.0	0	0.0

NEAR SEPTIC SYSTEM	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 59	20.3	9	15.3	12	20.3
100 ft. - 1/8 mile	: 54	18.6	11	20.4	13	24.1

NEAR SURFACE WATER	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 29	10.0	9	31.0	6	20.7
100 ft. - 1/8 mile	: 101	34.8	21	20.8	22	21.8

is the number of wells or detections in that category.
 % is the percentage of wells or detections in that category.

DEPRESSION AROUND WELL	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Yes	: 12	4.1	2	16.7	2	16.7
No	: 276	95.2	40	14.5	56	20.3
Unknown	: 2	0.0	1	50.0	1	50.0

NEAR CHEMICAL USAGE, MIXING, OR STORAGE	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Pesticides	: 18	6.2	5	27.8	5	27.8
Fertilizer	: 6	2.1	3	50.0	2	33.3
Petroleum	: 33	11.4	8	24.2	9	27.3
Other	: 3	1.0	0	0.0	0	0.0

NEAR PESTICIDE USAGE, MIXING, OR STORAGE	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 7	1.7	1	14.3	2	28.6
100 ft. - 1/8 mile	: 11	3.4	4	36.4	3	27.3

NEAR FERTILIZER USAGE, MIXING, OR STORAGE	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 2	0.7	2	100.0	1	50.0
100 ft. - 1/8 mile	: 4	1.4	1	25.0	1	25.0

NEAR PETROLEUM STORAGE	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 15	5.2	4	26.7	3	20.0
100 ft. - 1/8 mile	: 18	6.2	5	27.8	6	33.3

CROPS CLOSE TO WELL	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Small Grains	: 76	26.2	9	11.8	13	17.1
Row Crops	: 167	57.6	25	15.0	38	22.8
Hay	: 83	28.6	6	7.2	23	27.7
Pasture	: 97	33.4	13	13.4	18	18.6
C.R.P.	: 33	11.4	2	6.1	5	15.2

NEAR SMALL GRAIN CROPS	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 36	12.4	6	16.7	4	11.1
100 ft. - 1/8 mile	: 40	13.8	3	7.5	9	22.5

NEAR ROW CROPS	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 72	24.8	12	16.7	15	20.8
100 ft. - 1/8 mile	: 95	32.8	13	13.7	23	24.2

NEAR HAY CROPS	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 48	16.6	4	8.3	13	27.1
100 ft. - 1/8 mile	: 35	12.1	2	5.7	10	28.6

NEAR PASTURE	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 63	21.7	11	17.5	12	19.0
100 ft. - 1/8 mile	: 34	11.7	2	5.9	6	17.6

NEAR C.R.P.	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
0 - 100 ft.	: 21	7.2	2	9.5	3	14.3
100 ft. - 1/8 mile	: 12	4.1	0	0.0	2	16.7

Because of the greater number of nitrate detections compared to pesticide detections, however, it was possible to relate nitrate detections to site-inventory data, as depicted in Figures 13 through 15. Figure 13 depicts the percentage of nitrate plus nitrite detections versus general setting at various nitrate concentrations. There was not a great deal of distinction among the various settings with the overall percentages of nitrate detections ranging from approximately 20 percent to 24 percent. The general setting of a well located in a farmyard had the greatest percentage of nitrate detections at 24 percent. Wells located in close proximity to CRP land had the highest percentages of intermediate-concentrations (14.3 percent) and high-concentration nitrate detections at or above the MCL of 10 mg/l (N) (7 percent); however, few wells were sampled in that category. Often the sites had characteristics of more than one type of general setting; for example, a well located on the boundary of a farmyard and a pasture, adjacent to a road ditch. In 1995, an additional general setting data field was added to the inventory form and to the database to help account for wells with characteristics of more than one setting.

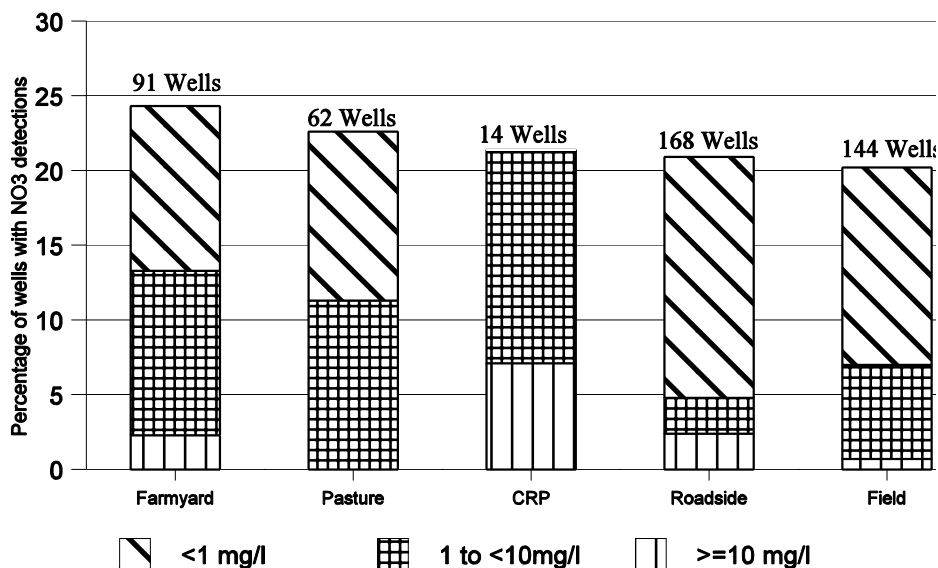


FIGURE 13. Graph of nitrate detections vs. general setting

An attempt was made to relate various factors of land use and their distance from the well to greater percentages of pesticide and nitrate detections. As depicted in Figure 14, close proximity to irrigation was associated with the greatest overall percentage of nitrate detections at 29 percent; however, there was not a large difference in the overall percentages for the various factors, ranging from approximately 21 percent to 29 percent. The greatest percentages of pesticide detections, 26.7 percent, and nitrate detections at or above the 10 mg/l (N) MCL, slightly over 8 percent, were associated with wells located in depressions. Shorter distance from the well did seem to link greater percentages of both pesticide and nitrate detections to irrigation; a greater percentage of pesticide detections to feedlots and surface water; and a greater percentage of nitrate detections to areas of chemical usage

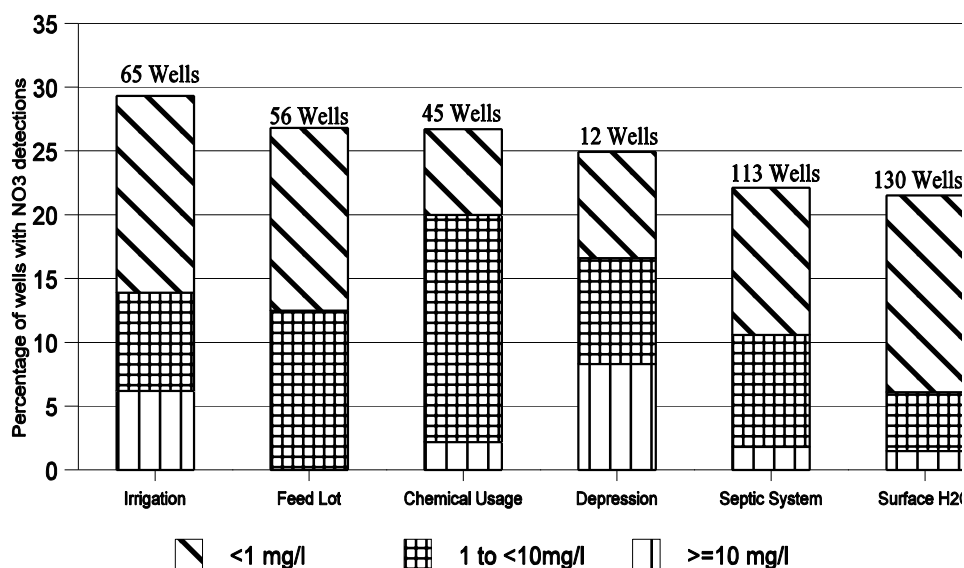


FIGURE 14. Graph of nitrate detections vs. other factors of possible influence within one-eighth mile of the well

Again, it should be noted that in some of these categories, few wells were sampled; therefore, confidence levels concerning those percentages are low. Because landowners around monitoring wells generally were not interviewed, numbers relating to verified chemical or fertilizer usage, mixing and storage are greatly understated. In addition, landowners who were interviewed rarely indicated chemical or fertilizer usage, mixing or storage in areas surrounding privately owned domestic, stock or irrigation wells, although it could be assumed that these activities probably have occurred more often than was reported.

As depicted in Figure 15, wells in close proximity to hay land had the highest percentage of nitrate detections for the various crop types, at almost 28 percent, as well as the greatest percentages of high- and intermediate-concentration detections at approximately 4 percent and 11 percent, respectively. The greatest percentage of wells with pesticide detections, 15 percent, was associated with row crops. Distances from pasture land to the well did seem to relate to greater percentages of both nitrate and pesticide detections. However, it should be noted that the percentage of wells with pesticide detections seemed to relate to shorter distance from the well for *all* crop types, with no corresponding relationship in percentage of nitrate detections.

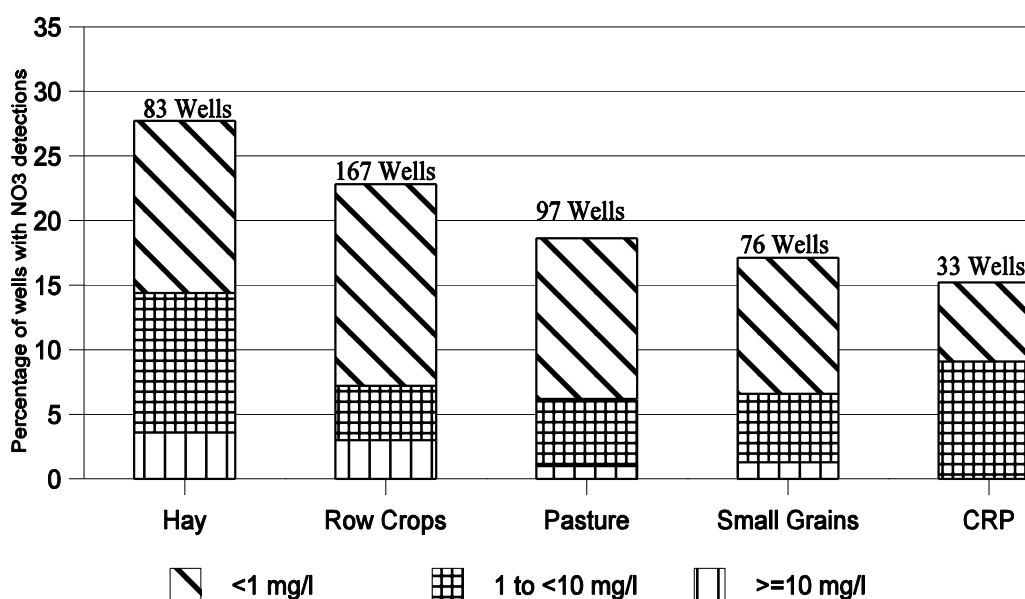


FIGURE 15. Graph of nitrate detections vs. crop type

It must be stated that the relationship of two variables, in this case the occurrence of greater percentages of nitrate detections related to various well-construction or site-inventory factors, does not necessarily imply a cause-and-effect relationship. None of the well-construction and site-inventory factors are necessarily independent, and some may have a cumulative effect on water quality. Within this study there is not enough specific data to determine all of the interrelationships of the factors. There also are factors that are inadequately accounted for, or not accounted for at all, such as chemical usage and precipitation. A higher percentage of nitrate detections for any one factor indicates only that there is a somewhat higher possibility of that

factor having an influence on water quality in this sample population. It should be noted that statistical analysis and comparison of the various factors performed on the sample set as a whole and on each of several subset populations for the first five-year monitoring cycle, 1992 through 1996, determined that many of the nitrate-detection relationships remain when looking at larger groups of wells.

SUMMARY AND CONCLUSIONS

Two hundred ninety wells from five glacial drift aquifers were sampled for general anion and cation chemistry, nitrate plus nitrite, and 60 selected pesticides and pesticide degradation products. Forty-three wells, or approximately 15 percent of the wells sampled, contained detectable concentrations of pesticides in at least one of the sampling periods. The Sheyenne Delta aquifer had 17 wells with pesticide detections; the Hankinson aquifer, eight; the Galesburg/Page aquifer, seven; the Milnor Channel aquifer, six; and the Kidder/Marstonmoor Plain aquifer, five. Twenty pesticide species were identified by laboratory analysis: atrazine, bentazon, bromoxynil, carbaryl, cyanazine, 2,4-D, DDT, dicamba, diclofop methyl, dichlorprop, endosulfan I, endosulfan sulfate, endrin, endrin ketone, malathion, pentachlorophenol, picloram, simazine, 2,4,5-T and trifluralin.

Most concentrations of the detected pesticides were far below their respective MCLs or HALs. The highest concentration of a detected pesticide was of 2,4-D at $5.11 \mu\text{g/l}$, or 7.3 percent of the MCL. The highest concentrations of detected pesticides in relation to a health-based standard were of cyanazine at $0.711 \mu\text{g/l}$, or 71.1 percent of the HAL, and atrazine at $0.807 \mu\text{g/l}$, or 26.9 percent of the MCL. These are significant because they exceeded the prevention action level (PAL) of the Pesticide State Management Plan (PSMP) set at 25 percent of the MCL or HAL. If a pesticide is detected in groundwater at concentrations at or above the PAL, a second water sample will be collected from the well at least 30 days after the first sample. If the second sample confirms a detection above the PAL, the regulatory portion of the PSMP will be engaged. Both of the above wells were resampled in accordance with the PSMP; no pesticides were detected upon resampling. Picloram was the pesticide found most frequently and the one most often confirmed in duplicate or follow-up samples. All concentrations of picloram were less than 1 percent of the MCL. Other pesticide concentrations detected ranged from 0.012 to 23 percent

of their respective MCL or HAL. In addition to picloram, pesticides confirmed in either duplicate or follow-up samples were bentazon, dicamba, malathion and trifluralin. Several pesticide detections, of picloram in particular, appear to be associated with a point source of contamination, most likely the spraying of road ditches for leafy spurge control. Detections of pentachlorophenol in seven wells were attributed to probable laboratory contamination. Sample contamination also may be the cause of some of the other pesticide detections -- of DDT, in particular, because its characteristic of adsorbing so strongly to soil gives it a very low leaching potential.

Nitrate was found above the 0.05 mg/l (N) minimum detection limit in 59 wells, or approximately 20 percent of the wells sampled. The concentration of nitrate was above the 10 mg/l (N) MCL in five wells, or 1.7 percent of the total wells sampled. Of the wells with nitrate detections, almost two-thirds had concentrations less than 1.0 mg/l (N). Several nitrate detections seem to be associated with non-point source activities or could not be identified as either point or non-point source. Past monitoring has demonstrated that many of the pesticide detections and the majority of the nitrate detections were probably associated with a point source of contamination. However, recent monitoring results indicate that in a few aquifers, at least, pesticide and nitrate detections appear to be attributable to non-point activities such as irrigation and over-application of farm chemicals.

In 1999, shallow depth of the well; shallow depth to the top of the screened interval; shorter distance from the water table to the top of the screen; livestock wells; and proximity to farmyards, irrigation and hay land were the factors associated with the highest percentages of nitrate detections.

Comparing the 1999 results to those of previous years, the percentage of wells with pesticide detections is approximately one and one-half times that of 1998, three times that of 1996, four times that of 1997, and seven and one-half times those of 1992 and 1995. The percentage of pesticide detections is only slightly less than the percentages encountered in 1993 and 1994, when flooding and heavy precipitation had an apparent effect on groundwater quality. Although snowfall during the winter of 1998-1999 was relatively light compared to other years, some areas of North Dakota experienced heavy precipitation the preceding summer. When monitoring of the Sheyenne Delta aquifer was conducted in April 1999, entire fields were under water and in many

wells groundwater levels were only a foot or two below the surface of the ground. Pesticides were detected in 17 wells in the Sheyenne Delta aquifer in 1999; this is comparable to the results of the 1994 monitoring when pesticides were detected in 16 wells in the aquifer.

Similarly, the nearby Hankinson and Milnor Channel aquifers also were probably affected by the heavy precipitation of the previous summer.

In 1999, the percentage of wells with nitrate detections was the lowest recorded since the beginning of the monitoring program, at just over 20 percent. It should be noted that prior to the 1995 monitoring year, a nitrate-detection level of greater than or equal to 0.02 mg/l (N) was used for reporting nitrate detections. For this report, all nitrate-detection data has been corrected to a standard minimum detection level of greater than or equal to 0.05 mg/l (N) for the monitoring period. Correcting the 1994 data to a standard minimum detection level of greater than or equal to 0.05 mg/l (N), the percentage of wells with nitrate detections was 43 percent, still more than twice that of 1999. In 1999, the percentage of wells with nitrate concentrations at or above the 10 mg/l (N) MCL was 1.7 percent, also the lowest recorded since the beginning of the monitoring program. The previous low was 2.7 percent, recorded in 1994 when many of the same aquifers were monitored for the first time. It should be noted that almost twice as many wells were sampled in 1999 (290 wells) than in 1994 (149 wells). Different aquifers were monitored each year of the study from 1992 to 1996. In 1997, 1998 and 1999, resampling was conducted of those aquifers initially sampled in 1992, 1993 and 1994; however, new aquifers also were added to the monitoring schedule. Therefore, these percentages do not attempt to draw a direct comparison from one year to another, but rather, illustrate the variability in detections from year to year, which may be due to different aquifers monitored, varying climatic conditions, or any number of factors.

In 1999, the Galesburg/Page, Hankinson, Kidder/Marstonmoor Plain, Milnor Channel and Sheyenne Delta aquifers underwent their first five-year resampling since 1994. The Sand Prairie aquifer, also sampled in 1994, was not resampled in 1999 pending the installation of additional monitoring wells. Therefore, the Sand Prairie aquifer will be included in the 2000 monitoring schedule and report. Other changes from the 1994 monitoring were the combining of that portion of the Marstonmoor Plain aquifer located in Kidder County and the Tappen aquifer (sampled for the monitoring program in 1996) with the Kidder County aquifer, now collectively

designated the Kidder aquifer system. The Stutsman County portion of the Marstonmoor Plain aquifer is still known by that name. For the purposes of this report, we treated these as a single entity and refer to it as the Kidder/Marstonmoor Plain aquifer.

An attempt was made to resample the same wells; however, this was not always possible. In some cases the well was no longer in existence or had been damaged so that the integrity of the well was in question, several of the wells originally sampled could not be reached because of wet conditions and, in some instances, attempts to contact landowners for permission to sample a well were unsuccessful. In 1994, 149 wells were sampled in the six above-mentioned aquifers (including Sand Prairie, in which six wells were sampled, one with a pesticide detection and five with nitrate detections, all below the MCL). Twenty-six wells, approximately 17 percent, contained detectable concentrations of pesticides. Eighteen of the original 26 wells with pesticide detections were resampled in 1999; pesticides were detected in the resample from seven of the wells. Of the pesticides detected in those seven wells in 1994, picloram was detected in six of the wells; picloram again was detected in five of the six wells in 1999, illustrating how persistent picloram is in the environment. The sample from the sixth well with a picloram detection in 1994 had detections of two different pesticides in 1999. Another well, in which atrazine was the only pesticide detected in 1994, had concentrations of four pesticides detected in 1999, including atrazine. Four of the wells with repeat pesticide detections are in the Sheyenne Delta aquifer, and the Galesburg/Page, Hankinson and Milnor Channel aquifers each had one well with a repeat detection. No pesticides were detected in the Tappen aquifer when it was sampled in 1996. Thirty-four of the 36 wells sampled in 1996 were resampled in 1999. Three of the five wells with pesticide detections in the Kidder/Marstonmoor Plain aquifer in 1999 were among the Tappen wells sampled in 1996.

In all five aquifers, the overall percentage of wells with nitrate detections decreased from 1994 to 1999, with decreases in the individual aquifers ranging from approximately 10 percent to 75 percent, except for the Milnor Channel aquifer in which the decrease in the overall percentage of wells with nitrate detections was very slight -- less than 1 percent. More wells were sampled in all five aquifers in 1999 than in 1994 -- in one aquifer, almost twice as many wells, and in another, three times as many. The fact that there was a much greater population of wells might suggest that the decreases may have been due to a dilution effect. However, when comparing only the wells sampled in both years, this same general trend was observed. This is most evident

in the Hankinson aquifer: a comparison of the 12 wells sampled in both 1994 and 1999 shows the decrease in the percentage of wells with nitrate detections was 100 percent, because none of the wells with nitrate detections in 1994 had repeat detections in 1999. In a few of the aquifers, the decrease in the overall percentage of wells with nitrate detections, when comparing the same wells sampled both years, was almost identical to that observed when comparing the total wells sampled both years. The only exception was the Milnor Channel aquifer in which a comparison of the 28 wells sampled both years shows the overall percentage of wells with nitrate detections to be the same at slightly over 21 percent for both 1994 and 1999.

Similarly, the percentages of wells with low-, intermediate- and high-concentration detections generally decreased from 1994 to 1999, with only a few exceptions, both when comparing the total wells sampled in both years and the same wells sampled both years. Two of the five aquifers had decreases in the percentage of wells for all concentration intervals from 1994 to 1999. In many cases, changes in the percentages of wells for the various concentration intervals were attributable to an increase or decrease of only one or two wells in that category.

The number of wells with nitrate detections also decreased in three of the five aquifers, most notably in the Hankinson aquifer. In 1994, 19 of the 20 wells sampled in the aquifer had nitrate detected at or above 0.05 mg/l; in 1999, six of the 25 wells sampled contained nitrates. The Galesburg/Page and Milnor Channel aquifers had slight increases in the actual number of wells with nitrate detections – from five to seven, and from six to 11 wells, respectively.

Based upon the data collected, pesticide contamination of groundwater in the aquifers sampled in 1999 is comparable to that of other years. Although pesticides were detected in almost 15 percent of the wells sampled in 1999, this percentage is lower than those encountered in 1993 and 1994, when flooding and heavy precipitation may have had an impact on groundwater quality. If the samples with probable and suspected contamination from laboratory and/or other sources were not included in the above figure, both the number and percentage of wells with pesticide detections would be notably less. This only serves to emphasize the necessity for confirmation resampling of pesticide detections. Resampling of wells shows that the occurrence of pesticides in this study, even in the same well, is highly variable and often of short duration. The percentages of nitrates detected in the aquifers monitored in 1999 appear to show an overall decrease in nitrate contamination, not only within those aquifers, but also when comparing them

to aquifers sampled in other years of the monitoring program. However, nitrate concentrations in specific individual wells have the potential to cause adverse health impacts to those well users.

Because of the apparent relationship between contaminant detections and several well-construction and/or site-activity factors, it is recommended that non-point and especially point source activities should be conducted carefully to prevent future contamination. Placement of drinking water wells should avoid areas of potential point sources of contamination, and they should be constructed to prevent direct contamination of the well from surface activities.

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APPENDIX A

Site Inventory Form

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AMBIENT GROUNDWATER MONITORING SITE INVENTORY

Site ID/Sample # _____		Project Code _____		Sample Type(s): Reg. Dup. Blank	
Date _____	Time _____	D/B Time _____	Collector(s) _____		
Analyses: Pesticides _____		Carbamates _____		Metals _____	
Nitrates _____		All of the Above _____		Other _____	
Weather Conditions _____					
Latitude/Longitude Field Reading _____					
Comments: _____					

OWNER INFORMATION			
Owner _____		Renter:	Yes No
c/o _____			
Address _____		Phone# () _____	- _____
City _____		State _____	Zip Code _____
Contact Person _____		Rel. To owner _____	
Comments: _____			

WELL INFORMATION			
Well name or # other than ID _____			
Casing diameter _____		Completed well depth _____	
Casing material: PVC Stainless Steel Iron Wood Masonry Other _____			
Pump type: Bailer Submersible Jet Hand/Windmill Bladder Other _____			
Ground elevation _____		Date constructed _____	
Top open interval _____		Bottom open interval _____	
Water use: Domestic Public Stock Observation Irrigation Industrial Other _____			
Well construction: Rotary Bored/Auger Dug Sand Point Cable Other _____			
Well is used: Daily Seasonally Backup Observation Other _____			
Protective cap: Yes No Unknown		Properly sealed: Yes No Unknown	
Sampling point _____		Aquifer _____	
County _____		Driller _____	
Comments: _____			

SITE DATA			
Depression around casing:		Yes	No
Near irrigation:		Yes	No
Recent precipitation:		Yes	No
Topography:		Flat	Sloping
		Rolling	Hilly
		Other	
		Unknown	
Distance:		0-100'	100'-1/8 mile
Amount			
Comments: _____			

CHEMICAL USAGE NEAR WELL

Pesticides **Fertilizer** **Petroleum - UST, AST** **Other** _____
 Chemical name _____ Date put in area _____
Store _____ **Mix** _____ **Load** _____ **Apply** _____ **Dispose** _____
 Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Pesticides **Fertilizer** **Petroleum - UST, AST** **Other** _____
 Chemical name _____ Date put in area _____
Store _____ **Mix** _____ **Load** _____ **Apply** _____ **Dispose** _____
 Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Pesticides **Fertilizer** **Petroleum - UST, AST** **Other** _____
 Chemical name _____ Date put in area _____
Store _____ **Mix** _____ **Load** _____ **Apply** _____ **Dispose** _____
 Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Comments: _____

Have there been any nearby chemical spills? **Yes** **No** **Unknown**
 Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**
 Recent change in water quality? **Yes** **No** **Unknown** **When?** _____
 Taste **Odor** **Color** **Appearance** **Other** _____
 Previous chemical/bacteriological analyses? **Yes** **No** **Unknown**
 Results: _____

Comments: _____

CROPS NEAR WELL

Small Grains **Row Crops** **Hay** **Pasture** **CRP**
 Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Small Grains **Row Crops** **Hay** **Pasture** **CRP**
 Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Small Grains **Row Crops** **Hay** **Pasture** **CRP**
 Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Small Grains **Row Crops** **Hay** **Pasture** **CRP**
 Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Comments: _____

NEARBY FACTORS OF POSSIBLE INFLUENCE

Feedlots	Disposal area	Septic system	Surface water	Other _____
Gradient from well:	Up Down	Both Even	Distance from well:	0-100' 100'-1/8 mile

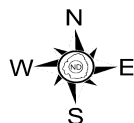
Feedlots	Disposal area	Septic system	Surface water	Other _____
Gradient from well:	Up Down	Both Even	Distance from well:	0-100' 100'-1/8 mile

Feedlots	Disposal area	Septic system	Surface water	Other _____
Gradient from well:	Up Down	Both Even	Distance from well:	0-100' 100'-1/8 mile

Feedlots	Disposal area	Septic system	Surface water	Other _____
Gradient from well:	Up Down	Both Even	Distance from well:	0-100' 100'-1/8 mile

Feedlots	Disposal area	Septic system	Surface water	Other _____
Gradient from well:	Up Down	Both Even	Distance from well:	0-100' 100'-1/8 mile

Comments:



Comments:

Draw a general map of the area - section / ¼ section / farmsite / etc. Locate wells, buildings, crops, and other operations that may impact water quality.

WELL STABILIZATION DATA

Site ID/Sample # _____ Date _____

Type of pump _____ Pumping rate _____

Regular sample time _____ Duplicate/Blank sample time _____

Time	Temperature	pH	Temperature-corrected Conductivity (μ mhos/cm)	Volume of Water Removed From Well (Cumulative)

Well depth from top of casing*
-Casing length from top to ground
 = Well depth

Water level from top of casing
-Casing length from top to ground
 = Depth to water

Well depth _____
-Depth to water _____
 =Lineal feet _____ X _____ = _____ (Volume of water in casing)
 (*Measurements to nearest 0.01 ft. before pumping or bailing)

Calculate one well volume using the table below:

Well diameter in inches:	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	3	4	6
Gallons per lineal foot of water in well:	0.023	0.04	0.06	0.09	0.16	0.37	0.67	1.47
Liters per lineal foot of water in well:	0.087	0.15	0.24	0.34	0.60	1.4	2.53	5.56

(Gallons x 3.7853 = liters)

Liters x.2642 = gallons)

WELL SETTING

Primary setting: Farmyard Field Pasture CRP Roadside Town
 Secondary setting: Farmyard Field Pasture CRP Roadside Town

Color _____ Appearance _____
 Odor _____ Taste _____

Comments: _____

APPENDIX B

General Inorganic Water Quality Analyses

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*** GALESBURG/PAGE AQUIFER ***

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
14205403DDDD3	2.6	27.1	30.7	4.9	79.7	0.419	7.75	0.48		6.93	< 1	362.	< 1	296.	608.	53.2< 0.05	311.	18.	104.	1.7	0.06	348.	
14205408DDDD	2.0	15.2	33.6	6.3	73.6	0.356	0.671	0.96		7.06	< 1	298.	< 1	244.	498.	39.2< 0.05	247.	14.	3.20	1.7	0.06	286.	
14205410CDD	40.2	32.9	31.2	8.3	148.	1.32	0.277	5.24		6.86	< 1	414.	< 1	339.	1060	271.< 0.05	505.	30.	3.52	14.4	0.78	712.	
14205415AAA	10.6	31.3	45.5	7.1	90.7	0.895	15.4	0.79		7.18	< 1	433.	< 1	355.	628.	18.4< 0.05	356.	21.	197.	5.9	0.24	374.	
14205416BAA2	< 0.1	29.7	64.6	4.1	103.	1.36	15.3	0.92		7.12	< 1	391.	< 1	320.	593.	37.2< 0.05	380.	22.	263.	0.1	0.00	370.	
14205422AAA	< 0.1	9.3	14.9	5.0	40.4	0.406	5.19	0.31		6.64	< 1	182.	< 1	149.	271.	6.8< 0.05	139.	8.	24.6	0.1	0.00	154.	
14205422AAA	< 3	12.3	15.5	5.4	54.0	0.605	6.86	0.63		7.07	< 1	233.	< 1	191.	376.	11.5< 0.05	186.	11.	55.5	3.3	0.10	204.	
14205424BBB	4.8	21.9	83.6	6.5	135.	6.31	103.	2.57		7.27	< 1	366.	< 1	300.	755.	134.< 0.05	428.	25.	1610	2.3	0.10	487.	
14205427DCC2	14.6	41.5	46.6	9.0	144.	0.954	10.7	1.05		7.05	< 1	474.	< 1	388.	946.	181.< 0.05	531.	31.	170.	5.5	0.28	627.	
14205429AAA3	8.6	23.8	54.0	7.2	98.5	1.13	9.66	1.44		7.02	< 1	362.	< 1	296.	563.	32.5< 0.05	344.	20.	151.	5.0	0.20	352.	
14205432CCC	47.6	36.1	29.7	10.3	155.	1.10	0.651	3.70		7.06	< 1	365.	< 1	299.	1120	330.< 0.05	536.	31.	3.70	15.8	0.89	765.	
14205434AAD3	27.4	90.9	41.3	6.3	138.	0.348	5.15	1.47		7.07	< 1	385.	< 1	315.	1270	466.< 0.05	719.	42.	62.8	7.5	0.44	922.	
14205512DDDD2	83.7	22.7	36.8	9.1	100.	0.846	2.55	3.21		6.69	< 1	406.	< 1	333.	893.	167.< 0.05	343.	20.	13.9	33.8	1.96	588.	
14205513CCC	42.3	17.5	57.1	6.7	79.9	1.95	15.6	2.19		6.96	< 1	349.	< 1	286.	664.	91.5< 0.05	272.	16.	334.	24.6	1.12	414.	
14205536AAA2	49.1	24.7	50.2	10.0	101.	1.34	7.86	2.06		7.00	< 1	391.	< 1	320.	755.	114.< 0.05	354.	21.	169.	22.5	1.13	496.	
14305401DDD	15.8	44.9	32.1	9.8	193.	1.63	4.94	3.67		6.75	< 1	480.	< 1	393.	1220	344.< 0.05	667.	39.	57.4	4.8	0.27	850.	
14305401DDD	17.5	46.8	32.1	10.1	199.	1.73	5.52	4.02		7.07	< 1	445.	< 1	364.	1230	351.< 0.05	690.	40.	68.6	5.1	0.29	850.	
14305404CCC	32.4	29.4	5.15	8.9	29.1	0.146	3.87	3.21		7.52	< 1	247.	< 1	202.	529.	93.9< 0.05	194.	11.	47.3	25.5	1.01	321.	
14305404CCC	29.0	36.0	28.1	9.0	132.	1.14	5.90	2.68		7.09	< 1	404.	< 1	331.	1010	216.< 0.05	478.	28.	73.0	11.4	0.58	626.	
14305415BBB2	16.2	66.2	5.79	12.0	15.5	0.046	4.03	2.72		7.04	< 1	349.	< 1	286.	598.	60.4< 0.05	311.	18.	117.	9.7	0.40	347.	
14305415BBB2	14.4	54.8	33.0	9.1	176.	1.25	89.8	3.28		6.86	< 1	392.	< 1	321.	1240	361.< 0.05	666.	39.	310.	4.4	0.24	814.	
14305418ABB	35.5	44.7	28.4	8.9	167.	1.25	6.58	4.66		7.08	< 1	445.	< 1	364.	1170	314.< 0.05	601.	35.	70.5	11.1	0.63	796.	
14305420ADD	12.2	29.1	19.6	7.6	65.5	0.269	3.95	2.16		7.31	< 1	259.	< 1	212.	609.	128. 0.13	283.	17.	41.7	8.3	0.32	375.	
14305420ADD	13.1	29.8	28.8	7.2	124.	1.02	2.67	1.99		7.05	< 1	360.	< 1	295.	840.	172.< 0.05	433.	25.	13.5	6.0	0.27	528.	
14305424DDDD2	56.6	51.8	6.76	12.6	10.9	0.115	6.51	6.55		9.02	31.	129.	< 1	157.	699.	218.< 0.05	240.	14.	28.0	32.3	1.59	452.	
14305424DDDD2	57.3	53.1	27.4	11.8	168.	0.707	31.9	7.60		6.90	< 1	440.	< 1	360.	1360	407.< 0.05	639.	37.	286.	15.9	0.99	924.	
14305432BBB	10.1	23.8	4.78	10.0	50.7	0.090	1.30	1.52		8.03	< 1	333.	< 1	273.	480.	14.1< 0.05	225.	13.	6.20	8.4	0.29	276.	
14305432BBB	16.8	29.3	28.8	9.0	125.	1.58	7.89	2.20		7.04	< 1	370.	< 1	303.	865.	183.< 0.05	433.	25.	34.5	7.6	0.35	550.	
14305515ABA2	87.3	44.1	56.2	11.8	166.	2.10	9.89	4.32		6.97	< 1	411.	< 1	337.	1240	373.< 0.05	596.	35.	181.	23.6	1.55	891.	
14305517ABA	62.0	54.0	30.4	7.0	120.	< 0.002	< 0.007	34.6		7.14	< 1	607.	< 1	497.	1200	127. 16.4	522.	31.	10.7	20.2	1.18	779.	
14405308CCC	9.8	47.3	41.6	8.3	94.0	0.542	8.67	10.3		7.16	< 1	330.	< 1	270.	811.	178. 0.09	430.	25.	64.7	4.6	0.21	513.	
14405327ABB	9.4	21.5	31.1	6.7	97.7	0.600	0.409	0.86		6.81	< 1	446.	< 1	365.	648.	26.8< 0.05	333.	19.	2.31	5.6	0.22	385.	
14405329ABD	5.5	20.6	31.3	5.7	88.4	0.446	0.347	4.72		6.83	< 1	384.	< 1	314.	603.	34.9< 0.05	306.	18.	2.37	3.7	0.14	351.	
14405406DDD	5.3	16.0	29.2	8.1	79.5	0.707	0.106	1.37		7.01	< 1	343.	< 1	281.	540.	25.4 0.10	265.	15.	5.10	4.0	0.14	307.	
14405406DDD	5.8	18.6	80.3	8.9	91.5	2.59	23.9	1.48		7.34	< 1	329.	< 1	269.	545.	33.8< 0.05	305.	18.	520.	3.8	0.14	324.	
14405409DAA	16.1	23.9	32.9	6.0	96.3	0.955	0.791	2.18		6.93	< 1	375.	< 1	307.	689.	87.5< 0.05	339.	20.	4.70	9.1	0.38	419.	
14405411DAD2	28.3	34.9	42.6	10.9	157.	1.46	4.39	4.16		6.98	< 1	472.	< 1	387.	1030	224.< 0.05	536.	31.	69.4	10.0	0.53	694.	
14405412DDDD2	20.5	28.2	31.7	8.1	127.	1.16	0.784	2.43		6.97	< 1	446.	< 1	365.	884.	154.< 0.05	434.	25.	8.10	9.1	0.43	562.	
14405417CCC	34.4	39.5	84.9	8.0	163.	5.56	38.9	4.12		6.89	< 1	471.	< 1	386.	1070	248.< 0.05	570.	33.	1010	11.4	0.63	731.	
14405419DDD	22.5	43.9	44.1	8.3	170.	1.80	4.63	5.27		7.00	< 1	445.	< 1	364.	1150	298.< 0.05	606.	35.	95.6	7.3	0.40	769.	
14405422ADD	2.2	23.7	36.9	7.2	111.	0.889	2.46	1.33		7.17	< 1	407.	< 1	333.	702.	71.0< 0.05	375.	22.	48.0	1.2	0.05	419.	
14405424CCC	2.6	15.8	25.6	4.3	44.3	0.194	1.02	0.84		7.39	< 1	199.	< 1	163.	365.	38.6< 0.05	176.	10.	3.90	3.0	0.09	207.	
14405424CCC	< 3	18.0	69.6	4.9	53.1	1.23	16.3	0.98		7.67	< 1	196.	< 1	161.	372.	44.4< 0.05	207.	12.	558.	3.0	0.09	223.	
14405428CCC	22.6	34.2	28.9	7.1	145.	1.34	0.281	2.65		6.83	< 1	429.	< 1	351.	922.	191.< 0.05	503.	29.	4.30	8.7	0.44	616.	
14405434CCC2	17.4	44.2	29.7	8.7	168.	1.44	1.01	2.14		6.86	< 1	481.	< 1	394.	1040	235.< 0.05	602.	35.	201.	5.8	0.31	714.	

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption Ratio). CaCO3 is total hardness measured as calcium carbonate.

*** GALESBURG/PAGE AQUIFER (continued) ***

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
14405436AAA	16.1	49.4	32.1	9.5	194.	1.61	12.8	3.89		6.91	< 1	487.	< 1	399.	1230	328.	< 0.05	688.	40.	80.4	4.7	0.27	843.
14405506BBD	22.0	78.1	30.8	6.2	203.	0.931	0.837	19.2		6.71	< 1	454.	< 1	372.	1450	492.	< 0.05	829.	48.	5.00	5.4	0.33	1050
14405526DDD	26.3	38.0	28.7	7.8	146.	1.12	2.47	5.56		7.10	< 1	387.	< 1	317.	1020	251.	< 0.05	521.	30.	23.1	9.7	0.50	667.
14405534DCC2	10.3	22.2	30.8	4.5	92.7	0.744	1.08	1.56		6.71	< 1	341.	< 1	279.	671.	105.	< 0.05	323.	19.	11.1	6.3	0.25	406.
14405536BC	21.3	34.1	28.0	6.9	136.	0.990	0.817	1.82		6.80	< 1	390.	< 1	319.	873.	176.	< 0.05	480.	28.	5.40	8.6	0.42	570.
14505422AAA	15.9	38.2	30.3	10.4	147.	0.803	19.5	3.20		6.54	< 1	330.	< 1	270.	1040	311.	< 0.05	525.	31.	220.	6.0	0.30	690.
14505517CBC	65.1	86.6	29.2	4.7	205.	0.018	0.007	29.0		6.91	< 1	389.	< 1	319.	1640	609.	4.75	869.	51.	< 1	13.9	0.96	1210
14605329DCC	2.5	38.8	32.1	3.2	151.	1.17	0.592	2.50		6.91	< 1	293.	< 1	240.	1000	342.	< 0.05	537.	31.	4.20	1.0	0.05	686.
14605332ACB	4.4	37.5	31.1	2.8	138.	0.926	0.437	3.00		6.97	< 1	348.	< 1	285.	933.	255.	0.12	499.	29.	2.00	1.9	0.09	615.
14605333BBB	0.7	17.7	29.9	2.7	62.8	0.486	5.92	0.75		6.69	< 1	293.	< 1	240.	463.	24.8	< 0.05	230.	13.	77.1	0.6	0.02	256.
MINIMUM	< 0.1	9.3	4.78	2.7	10.9	< 0.002	< 0.007	0.31		6.54	< 1	129.	< 1	149.	271.	6.8	< 0.05	139.	8.	< 1	0.1	0.00	154.
MAXIMUM	87.3	90.9	84.9	12.6	205.	6.31	103.	34.6		9.02	31.	607.	< 1	497.	1640	609.	16.4	869.	51.	1610	33.8	1.96	1210
MEAN	21.8	35.4	35.4	7.7	117.2	1.130	9.82	4.1	.	7.05	1.1	374	0.5	307	854.2	184	0.41	438	26	137	8.9	0.4	558
MEDIAN	16.1	32.9	31.1	7.8	124.0	0.955	4.63	2.5	.	7.00	0.5	385	0.5	315	865.0	172	0.01	433	25	56	6.0	0.3	550
STDDEV	21.0	17.3	17.3	2.4	49.5	1.101	18.76	6.2	.	0.37	4.1	87	0.0	69	310.3	143	2.29	173	10	267	7.8	0.4	238

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption Ratio).
CaCO3 is total hardness measured as calcium carbonate.

***** HANKINSON AQUIFER *****

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
12904826ABB	42.7	114.	29.4	10.4	199.	0.816	4.93	197.		7.09	< 1	856.	< 1	701.	1910	167.	< 0.05	967.	56.	56.0	8.6	0.60	1150
12904826ABB	47.6	127.	23.6	31.1	178.	0.856	1.85	150.		7.02	< 1	740.	< 1	606.	1860	226.	2.46	968.	57.	20.3	9.3	0.67	1140
12904827CCCC2	8.4	39.4	30.0	3.9	102.	0.289	0.925	9.86		7.00	< 1	392.	< 1	321.	778.	127.	0.08	417.	24.	9.60	4.1	0.18	486.
12904833DDC	36.8	58.0	32.9	9.3	186.	0.278	3.41	7.71		6.95	< 1	537.	< 1	440.	1350	382.	< 0.05	704.	41.	17.5	10.0	0.60	946.
12904834CCCC2	25.0	50.2	31.3	8.4	156.	0.282	2.21	0.85		6.98	< 1	473.	< 1	387.	1140	306.	< 0.05	597.	35.	25.8	8.2	0.45	782.
12904906ACD	36.3	40.6	29.1	5.2	101.	0.492	0.666	68.1		7.08	< 1	415.	< 1	340.	852.	52.9	< 0.05	420.	25.	7.70	15.6	0.77	511.
12904908CDD	21.0	102.	23.6	7.4	223.	1.10	0.416	67.9		6.84	< 1	684.	< 1	560.	1660	395.	< 0.05	977.	57.	2.50	4.4	0.29	1160
12904910BDAD	38.1	96.0	34.3	48.8	252.	1.03	6.84	181.	0.39	6.83	< 1	849.	< 1	695.	2040	293.	< 0.05	1030	60.	71.5	7.0	0.52	1330
12904913BBB	39.1	45.3	35.8	6.6	105.	0.324	1.80	0.90		7.13	< 1	532.	< 1	436.	971.	128.	< 0.05	449.	26.	20.7	15.6	0.80	589.
12904916BAB	10.1	28.3	33.9	5.8	110.	0.459	1.10	14.2		7.06	< 1	410.	< 1	336.	745.	82.4	< 0.05	391.	23.	11.6	5.2	0.22	455.
12904916BAB	10.0	29.6	31.4	5.7	114.	0.480	1.21	16.9		7.32	< 1	385.	< 1	315.	776.	83.5	< 0.05	407.	24.	13.6	5.0	0.22	451.
12904918BBB2	2.5	37.4	30.7	4.0	85.0	0.329	1.03	4.12		7.11	< 1	380.	< 1	311.	658.	77.7	< 0.05	366.	21.	9.40	1.4	0.06	400.
12904920BBB	14.5	57.4	33.9	5.8	127.	0.583	2.51	57.9		7.15	< 1	485.	< 1	397.	1060	165.	< 0.05	554.	32.	22.3	5.3	0.27	669.
12904933BAC	72.2	25.0	32.1	9.4	98.0	0.203	1.11	3.66		7.11	< 1	391.	< 1	320.	920.	214.	< 0.05	348.	20.	12.8	30.3	1.68	617.
13004906BBD	19.8	36.5	33.6	4.1	104.	0.225	1.32	2.68		6.74	< 1	389.	< 1	319.	797.	150.	< 0.05	410.	24.	16.7	9.4	0.43	511.
13004929BCC	6.6	14.0	34.0	2.7	94.8	1.50	1.78	1.60		6.94	< 1	357.	< 1	292.	572.	47.6	< 0.05	295.	17.	14.9	4.6	0.17	345.
13004929BCC	6.8	14.8	32.0	2.7	100.	1.59	1.75	1.49		7.26	< 1	324.	< 1	265.	598.	48.9	< 0.05	311.	18.	25.5	4.5	0.17	336.
13004930ADD	1.7	9.5	30.7	2.6	61.8	0.883	0.327	1.95		6.99	< 1	245.	< 1	201.	382.	15.2	< 0.05	194.	11.	4.00	1.8	0.05	216.
13004931AAB2	150.	273.	34.9	39.1	415.	1.19	15.5	8.89	0.15	6.83	< 1	759.	< 1	622.	3410	1860	< 0.05	2160	126.	121.	12.8	1.40	3120
13005001AAA3	64.5	153.	56.0	15.3	478.	1.62	11.0	200.	0.20	6.83	< 1	450.	< 1	369.	2970	1360	0.18	1820	107.	49.4	7.0	0.66	2500
13005003AAB	2.7	22.0	33.4	2.3	88.1	0.595	1.03	10.2		6.99	< 1	356.	< 1	292.	569.	29.3	< 0.05	311.	18.	23.9	1.8	0.07	332.
13005006AAA2	3.9	14.3	31.2	2.8	86.7	0.524	0.093	1.10		7.16	< 1	313.	< 1	256.	470.	23.1	0.19	276.	16.	4.20	2.9	0.10	289.
13005006AAA2	4.5	14.7	30.2	3.1	96.6	0.703	0.255	0.64		7.36	< 1	355.	< 1	291.	557.	14.9	< 0.05	302.	18.	5.20	3.1	0.11	311.
13005008BAA2	1.5	26.6	31.4	2.4	85.4	0.198	0.148	5.46		7.42	< 1	286.	< 1	234.	601.	112.	0.14	323.	19.	4.40	1.0	0.04	377.
13005008BAA2	< 3	32.0	34.3	3.0	109.	0.923	2.43	11.1		7.20	< 1	242.	< 1	198.	709.	179.	< 0.05	404.	24.	43.3	1.6	0.06	458.
13005009AAD2	2.6	20.8	30.7	2.4	87.9	0.663	0.401	2.97		7.20	< 1	355.	< 1	291.	572.	34.7	< 0.05	305.	18.	5.00	1.8	0.06	328.
13005009AAD2	< 3	22.9	30.0	2.6	97.3	0.741	0.377	3.14		7.38	< 1	354.	< 1	290.	613.	48.7	< 0.05	337.	20.	8.40	1.9	0.07	354.
13005024DDD2	0.5	41.4	33.7	2.1	168.	1.04	1.17	32.8		6.77	< 1	417.	< 1	342.	1010	220.	< 0.05	590.	34.	11.6	0.2	0.01	672.
13105027CDD2	1.2	17.8	33.7	2.5	68.1	0.219	0.121	0.77		7.00	< 1	329.	< 1	269.	449.	7.26	< 0.05	243.	14.	1.74	1.0	0.03	262.
13105027CDD2	< 3	18.3	33.7	2.5	70.9	0.565	0.469	0.56		7.31	< 1	295.	< 1	242.	456.	6.9	< 0.05	253.	15.	5.90	2.5	0.08	250.
13105029CCCC2	3.4	21.9	34.0	3.1	105.	0.235	0.480	2.28		7.05	< 1	328.	< 1	269.	642.	108.	0.14	353.	21.	5.40	2.0	0.08	408.
13105032BCC	2.7	8.3	24.7	6.0	52.1	2.74	0.116	2.86		7.18	< 1	257.	< 1	210.	409.	2.4	< 0.05	164.	10.	50.4	3.3	0.09	203.
13105032BCC	< 3	17.3	30.2	3.0	101.	0.822	0.440	1.36		7.45	< 1	355.	< 1	291.	591.	21.2	< 0.05	324.	19.	5.00	1.9	0.07	324.

MINIMUM	0.5	8.3	23.6	2.1	52.1	0.198	0.093	0.56	0.15	6.74	< 1	242.	< 1	198.	382.	2.4	< 0.05	164.	10.	1.74	0.2	0.01	203.
MAXIMUM	150.	273.	56.0	48.8	478.	2.74	15.5	200.	0.39	7.45	< 1	856.	< 1	701.	3410	1860	2.46	2160	126.	121.	30.3	1.68	3120
MEAN	20.5	49.4	32.3	8.1	136.5	0.742	2.10	32.5	0.25	7.09	0.5	434	0.5	355	1003.0	212	0.11	544	32	21	5.9	0.3	676
MEDIAN	6.8	29.6	32.0	4.0	102.0	0.595	1.10	4.12	0.20	7.08	0.5	385	0.5	315	745.0	108	0.01	391	23	13	4.5	0.2	455
STDDEV	29.5	52.3	5.2	10.5	90.0	0.529	3.28	58.4	0.13	0.19	0.0	161	0.0	132	696.3	370	0.41	428	25	28	5.8	0.4	612

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption Ratio).
CaCO3 is total hardness measured as calcium carbonate.

***** Kidder/Marstonmoor Plain Aquifer *****

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
13807120BDD	180.	14.8	48.7	13.5	43.8	0.191	0.135	4.51		7.30	< 1	529.	< 1	433.	1080	163. < 0.05	170.	10.	< 1	67.5	6.00	682.	
13807201AAA2	16.4	27.6	21.3	4.2	73.2	0.834	8.10	1.82		7.09	< 1	340.	< 1	278.	607.	75.3< 0.05	297.	17.	173.	10.5	0.41	368.	
13807202CBA	95.0	15.2	22.0	8.9	47.2	0.797	0.085	5.48		7.35	< 1	358.	< 1	293.	754.	110. < 0.05	181.	11.	2.70	51.7	3.07	460.	
13807203AAA4	16.2	44.3	66.2	4.8	97.7	6.14	28.4	10.2		7.33	< 1	342.	< 1	280.	767.	154. 0.12	427.	25.	864.	7.5	0.34	498.	
13807207AAA2	89.1	15.7	25.5	7.7	65.3	0.704	3.06	6.02		6.85	< 1	413.	< 1	338.	800.	114. < 0.05	228.	13.	12.6	44.8	2.57	503.	
13807217AAA2	29.2	31.9	45.7	7.0	86.9	0.386	0.368	2.09		7.43	< 1	499.	< 1	409.	766.	41.8< 0.05	349.	20.	4.50	15.0	0.68	447.	
13807308DDD2	158.	14.3	24.6	8.1	48.4	0.709	2.10	40.3		7.34	< 1	564.	< 1	462.	1040	72.8< 0.05	180.	11.	15.9	64.3	5.12	622.	
13907001DDD	393.	16.2	29.1	11.4	69.4	0.712	0.090	267.	0.34	7.22	< 1	801.	< 1	656.	2220	143. < 0.05	240.	14.	< 1	77.0	11.0	1300	
13907003DDD	29.1	30.0	31.6	5.5	107.	1.28	0.419	30.1		6.90	< 1	398.	< 1	326.	840.	108. < 0.05	391.	23.	< 1	13.7	0.64	508.	
13907004DDA2	4.0	30.2	30.1	3.5	61.4	1.32	6.37	1.54		6.98	< 1	303.	< 1	248.	474.	30.7< 0.05	278.	16.	59.7	3.0	0.10	283.	
13907005DDC2	5.9	27.3	26.0	2.8	83.7	0.843	2.42	1.83		7.07	< 1	356.	< 1	292.	600.	54.3< 0.05	322.	19.	25.4	3.8	0.14	353.	
13907010ddb	4.8	31.2	28.5	3.6	105.	0.741	< 0.007	3.54		6.77	< 1	412.	< 1	337.	729.	81.8< 0.05	391.	23.	< 1	2.6	0.11	435.	
13907011AAA2	16.9	21.5	29.8	5.1	91.8	1.06	0.305	4.72		6.82	< 1	388.	< 1	318.	672.	64.2< 0.05	318.	19.	< 1	10.1	0.41	397.	
13907018CCC	8.2	23.8	19.6	5.2	73.7	0.256	1.19	1.69		7.39	< 1	335.	< 1	274.	568.	47.7 0.83	282.	16.	15.8	5.8	0.21	331.	
13907103BBB2	28.7	27.6	25.6	3.7	72.8	0.733	1.10	3.46		7.48	< 1	345.	< 1	283.	653.	87.2< 0.05	296.	17.	6.20	17.1	0.73	396.	
13907104CCC	12.8	22.7	26.7	4.6	76.0	0.644	3.47	2.21		6.97	< 1	343.	< 1	281.	587.	51.7< 0.05	283.	17.	41.5	8.7	0.33	341.	
13907105CCA	18.5	18.2	29.9	4.4	73.8	0.980	0.192	1.92		6.91	< 1	359.	< 1	294.	580.	39.3< 0.05	259.	15.	< 1	13.1	0.50	335.	
13907109AAA	12.8	29.3	32.4	4.9	89.4	1.19	2.03	6.32		7.18	< 1	379.	< 1	310.	679.	76.2< 0.05	344.	20.	23.4	7.3	0.30	408.	
13907110CDD	14.4	25.1	30.1	5.2	80.8	0.552	0.608	1.79		6.94	< 1	357.	< 1	292.	621.	69.2< 0.05	305.	18.	2.90	9.1	0.36	374.	
13907111AAA	16.2	25.4	27.2	5.3	70.5	0.628	1.86	1.52		6.96	< 1	332.	< 1	272.	592.	64.1< 0.05	281.	16.	20.0	10.9	0.42	349.	
13907112CCC	10.4	22.5	31.5	4.7	76.6	0.539	0.022	1.79		6.79	< 1	324.	< 1	265.	542.	45.7< 0.05	284.	17.	1.40	7.2	0.27	323.	
13907113CCC	41.2	22.4	46.8	7.1	70.0	1.65	11.7	5.74		7.32	< 1	318.	< 1	260.	598.	53.4 4.17	267.	16.	186.	24.4	1.10	377.	
13907114CBB	12.3	20.0	26.1	3.4	61.7	0.238	< 0.007	2.05		6.97	< 1	311.	< 1	255.	519.	36.6 0.89	237.	14.	< 1	10.0	0.35	295.	
13907114CBB	12.9	20.6	25.9	3.5	63.8	0.255	0.019	2.57		7.58	< 1	277.	< 1	227.	496.	36.0 1.48	244.	14.	2.40	10.1	0.36	284.	
13907117BBB2	11.9	20.6	23.3	3.2	48.3	0.332	8.95	1.66		7.64	< 1	255.	< 1	209.	353.	2.8< 0.05	206.	12.	19.6	10.9	0.36	216.	
13907118ABA	7.5	21.0	30.2	3.0	69.8	0.259	< 0.007	1.52		6.89	< 1	306.	< 1	251.	514.	34.0 2.24	261.	15.	< 1	5.8	0.20	300.	
13907121AAA	51.8	55.2	21.5	11.4	92.2	0.697	3.80	6.73		6.97	< 1	458.	< 1	375.	1000	200. < 0.05	458.	27.	45.4	19.2	1.05	645.	
13907129CCC2	42.6	27.0	20.3	6.3	71.1	0.849	2.57	6.92		6.93	< 1	315.	< 1	258.	721.	139. < 0.05	289.	17.	26.5	23.7	1.09	450.	
13907203DDD3	24.7	34.9	29.4	5.7	85.5	0.619	11.6	13.1		6.92	< 1	425.	< 1	348.	748.	72.3< 0.05	357.	21.	145.	12.8	0.57	448.	
13907208BBD	16.6	31.6	30.3	7.7	104.	0.903	0.263	2.38		7.16	< 1	458.	< 1	375.	770.	80.8< 0.05	390.	23.	28.7	8.2	0.37	471.	
13907219DDD	136.	19.3	30.2	10.9	59.9	1.48	3.21	4.19		7.19	< 1	425.	< 1	348.	950.	164. < 0.05	229.	13.	42.3	54.8	3.91	606.	
13907221BBB2	21.3	24.9	28.0	6.3	90.0	1.44	3.38	2.59		6.94	< 1	429.	< 1	351.	731.	74.3< 0.05	327.	19.	54.7	12.1	0.51	433.	
13907228BBB2	5.9	30.2	20.1	2.8	113.	1.29	0.767	0.57		7.07	< 1	471.	< 1	386.	738.	51.6< 0.05	407.	24.	4.40	3.0	0.13	438.	
13907231DDC4	29.5	24.5	26.0	6.5	94.7	0.936	2.32	3.46		6.90	< 1	416.	< 1	341.	748.	81.9< 0.05	338.	20.	9.80	15.6	0.70	448.	
13907234BBB3	454.	105.	28.5	41.0	25.6	0.386	2.71	37.5	0.17	7.86	< 1	1350	< 1	1110	2580	415. < 0.05	496.	29.	27.5	64.2	8.86	1750	
14007019AAA	19.6	39.3	21.3	4.2	130.	1.49	0.011	4.62		7.16	< 1	454.	< 1	372.	932.	178. < 0.05	487.	28.	< 1	7.9	0.39	601.	
14007030CCC	60.0	22.0	27.3	7.6	69.2	0.645	4.52	6.72		6.91	< 1	417.	< 1	342.	749.	80.5< 0.05	264.	15.	55.7	32.2	1.61	454.	
14007110CDD2	12.6	44.4	36.8	4.4	130.	1.77	8.96	3.33		6.90	< 1	392.	< 1	321.	864.	176. < 0.05	508.	30.	171.	5.0	0.24	566.	
14007113CCC	6.2	43.9	30.4	5.0	146.	1.45	3.45	28.9		6.80	< 1	431.	< 1	353.	941.	164. < 0.05	546.	32.	62.2	2.4	0.12	608.	
14007114BBB1	18.3	27.1	28.0	4.2	73.5	0.864	1.80	4.04		6.93	< 1	335.	< 1	274.	625.	73.2< 0.05	295.	17.	33.0	11.6	0.46	367.	
14007117AAA2	17.3	23.2	27.8	4.0	76.8	0.967	10.9	2.25		6.80	< 1	338.	< 1	277.	624.	79.8< 0.05	287.	17.	130.	11.3	0.44	372.	
14007119DDD3	221.	31.1	24.6	3.6	41.8	0.156	2.91	12.9		7.58	< 1	586.	< 1	480.	1270	193. 11.9	232.	14.	39.2	66.9	6.30	847.	
14007124DDD3	46.1	40.9	54.3	6.5	127.	2.60	11.4	4.65		7.00	< 1	411.	< 1	337.	889.	130. 10.5	486.	28.	312.	16.8	0.91	606.	
14007126CCC2	47.7	21.9	31.9	4.7	76.2	0.922	6.12	7.09		6.99	< 1	317.	< 1	260.	711.	130. < 0.05	281.	16.	71.7	26.5	1.24	446.	
14007127ABB2	18.4	34.6	17.5	3.9	123.	1.05	< 0.007	8.69		7.22	< 1	331.	< 1	271.	893.	186. 10.4	450.	26.	< 1	8.1	0.38	586.	
14007128DAA2	7.4	35.3	28.9	2.9	124.	1.01	2.20	23.6		6.86	< 1	265.	< 1	217.	866.	239. < 0.05	455.	27.	24.1	3.4	0.15	565.	
14007131AAA2	30.5	25.7	29.6	4.0	82.4	0.986	2.12	7.35		7.12	< 1	325.	< 1	266.	707.	124. < 0.05	312.	18.	22.8	17.2	0.75	436.	
14007132DAA	15.7	26.3	21.9	3.6	89.3	1.55	0.052	4.41		6.89	< 1	369.	< 1	302.	669.	87.6< 0.05	331.	19.	3.90	9.2	0.37	411.	
14007132DAA	10.7	25.5	28.9	3.1	86.9	1.50	< 0.01	4.65		7.56	< 1	306.	< 1	251.	614.	78.5< 0.05	322.	19.	< 1	6.6	0.26	362.	

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption Ratio). CaCO3 is total hardness measured as calcium carbonate.

*** Kidder/Marstonmoor Plain Aquifer (continued) ***

IDS	NA	MG	SIO2	K	CA	MN	FE	CL	F	PH	CO3	HCO3	OH	ALK	COND	SO4	N	CACO3	HARD	TURB	PCTNA	SAR	TDS
14007133CBB2	15.3	24.8	21.8	3.4	83.6	1.37	2.82	4.39		6.86	< 1	344.	< 1	282.	618.	75.5< 0.05	311.	18.		26.6	9.5	0.38	379.
14007134DDD1	10.0	23.3	32.4	3.1	78.4	0.973	4.31	3.78		6.88	< 1	312.	< 1	256.	564.	68.0< 0.05	292.	17.		71.6	6.8	0.25	342.
14007135DDDD2	9.9	33.7	25.7	3.7	107.	1.25	3.45	2.41		6.82	< 1	442.	< 1	362.	767.	94.5< 0.05	406.	24.		39.7	5.0	0.21	471.
14007227BBB4	144.	30.3	40.0	10.1	125.	1.09	5.55	9.49		6.87	< 1	566.	< 1	464.	1260	276. < 0.05	437.	26.		97.9	40.9	2.99	876.
14007228DDDD2	169.	26.1	20.5	10.7	83.2	1.42	1.61	9.11		7.25	< 1	547.	< 1	448.	1250	254. < 0.05	315.	18.		14.5	52.6	4.14	824.
14007233DDC4	44.5	46.1	55.1	7.8	88.4	0.805	14.2	1.86		7.07	< 1	425.	< 1	348.	738.	104. < 0.05	411.	24.		324.	18.6	0.95	504.
14007234CDD3	64.6	31.3	52.2	8.8	121.	2.65	18.7	5.76		6.80	< 1	486.	< 1	398.	934.	171. < 0.05	431.	25.		154.	24.0	1.35	644.
14007235DDDD2	65.5	16.8	20.9	7.3	69.5	1.04	0.880	24.1		7.31	< 1	339.	< 1	278.	744.	97.0< 0.05	243.	14.		7.60	36.0	1.83	449.
14106907DDDD2	48.1	87.1	24.1	15.1	128.	1.08	3.34	20.2		7.05	< 1	594.	< 1	486.	1340	300. < 0.05	678.	40.		37.1	13.0	0.80	893.
14107002CDD	35.7	131.	28.7	21.3	59.9	0.752	< 0.007	11.1		7.45	< 1	848.	< 1	695.	1270	75.5< 0.05	689.	40.		51.7	9.7	0.59	754.
14107012DDDD2	8.1	33.9	44.1	4.5	88.3	0.856	7.92	2.82		6.91	< 1	328.	< 1	269.	600.	39.1 9.45	360.	21.		165.	4.6	0.19	382.
14107013CDD2	3.9	23.8	24.8	4.1	77.6	< 0.002	< 0.007	1.31		7.06	< 1	389.	< 1	319.	555.	14.5 0.59	292.	17.		< 1	2.8	0.10	321.
14107014DCC2	5.3	28.2	27.4	2.4	69.4	< 0.002	< 0.007	0.60		7.10	< 1	346.	< 1	283.	546.	37.6 0.68	290.	17.		3.50	3.8	0.14	319.
14107108DAA2	6.6	31.3	40.3	3.1	93.4	2.79	9.25	3.57		6.98	< 1	277.	< 1	227.	565.	64.8 8.20	362.	21.		111.	3.8	0.15	378.
14107122AAA2	8.8	38.1	31.9	3.2	113.	0.752	4.12	1.69		7.26	< 1	540.	< 1	442.	759.	7.65 0.80	439.	26.		66.7	4.1	0.18	444.
14107201DDDD2	14.1	24.8	23.9	3.5	89.8	0.651	3.40	2.20		7.03	< 1	369.	< 1	302.	650.	87.0< 0.05	327.	19.		33.4	8.4	0.34	405.
14107234CDD	25.7	21.3	22.7	7.5	63.7	0.586	3.83	3.24		6.96	< 1	350.	< 1	287.	550.	36.9< 0.05	247.	14.		28.4	17.8	0.71	333.
14206907DCC	2.0	26.4	32.0	4.0	69.7	0.453	6.56	0.92		7.06	< 1	268.	< 1	219.	454.	12.8 8.77	283.	17.		152.	1.5	0.05	289.
14206919BBB2	3.0	28.2	20.7	3.2	83.1	0.670	0.570	1.17		6.94	< 1	334.	< 1	274.	589.	71.5 0.12	324.	19.		14.4	1.9	0.07	357.
14206922BCC	9.1	28.6	26.6	3.9	92.0	1.09	1.36	5.53		6.77	< 1	413.	< 1	338.	684.	55.9< 0.05	348.	20.		13.8	5.3	0.21	401.
14206928DDDD	22.5	56.1	20.2	18.1	101.	0.857	3.18	20.1		7.11	< 1	377.	< 1	309.	991.	230. < 0.05	483.	28.		23.6	8.8	0.44	636.
14206931DCC	11.3	24.8	52.6	5.4	96.1	2.70	10.1	4.01		7.03	< 1	366.	< 1	300.	639.	62.4< 0.05	342.	20.		186.	6.5	0.27	386.
14207004AAA	18.3	29.6	30.0	6.2	113.	1.50	0.471	2.18		6.90	< 1	429.	< 1	351.	824.	129. < 0.05	404.	24.		3.20	8.8	0.40	512.
14207011DCC	10.6	27.3	29.6	4.0	104.	1.43	0.549	2.30		6.89	< 1	384.	< 1	314.	721.	97.6< 0.05	372.	22.		6.60	5.7	0.24	437.
14207013ACC	2.0	26.4	28.9	2.7	81.5	0.598	< 0.007	2.26		6.99	< 1	322.	< 1	264.	582.	69.4< 0.05	312.	18.		< 1	1.4	0.05	345.
14207014BCC	6.5	24.5	27.7	4.1	93.9	1.02	0.057	6.16		6.89	< 1	353.	< 1	289.	658.	80.5< 0.05	336.	20.		2.20	4.0	0.15	392.
14207014BCC	6.0	25.2	26.7	4.0	97.2	1.04	0.126	17.3		7.54	< 1	317.	< 1	260.	656.	77.7< 0.05	347.	20.		2.30	3.6	0.14	386.
14207016BAD3	2.1	18.7	39.3	2.5	51.7	0.795	10.8	1.43		6.70	< 1	232.	< 1	190.	388.	30.9< 0.05	206.	12.		96.2	2.1	0.06	224.
14207018ABB	41.1	27.7	30.7	7.5	107.	1.27	1.36	4.14		6.96	< 1	482.	< 1	395.	869.	111. < 0.05	381.	22.		14.3	18.5	0.91	538.
14207019CDD3	53.6	119.	38.7	21.8	92.3	1.34	12.2	18.2		7.16	< 1	878.	< 1	719.	1390	157. < 0.05	720.	42.		85.9	13.4	0.87	897.
14207020BBB	8.7	29.2	45.5	6.4	104.	1.10	12.3	1.40		6.90	< 1	335.	< 1	274.	597.	70.8< 0.05	380.	22.		252.	4.6	0.19	388.
14207024BCC2	5.1	31.5	27.5	3.7	95.3	0.988	2.17	1.24		6.93	< 1	326.	< 1	267.	607.	82.3< 0.05	368.	21.		48.1	2.9	0.12	382.
14207028DAA2	3.9	20.5	25.9	2.8	65.3	0.137	0.019	0.84		7.07	< 1	302.	< 1	247.	482.	28.8 0.40	248.	14.		4.40	3.3	0.11	275.
14207110BBB	110.	32.9	20.6	10.6	114.	1.15	3.88	26.9		7.03	< 1	598.	< 1	490.	1170	172. < 0.05	420.	25.		39.0	35.4	2.33	763.
14207121AAA	82.5	29.8	21.0	10.0	89.7	0.800	3.34	21.9		7.03	< 1	522.	< 1	428.	953.	109. < 0.05	347.	20.		36.7	33.2	1.93	602.
14207132CDD2	6.3	26.4	23.1	3.2	70.3	0.535	3.34	2.24		6.99	< 1	305.	< 1	250.	521.	49.3< 0.05	284.	17.		27.6	4.5	0.16	310.
14207216BBB2	21.2	31.9	21.9	4.2	72.6	0.123	1.70	2.00		7.61	< 1	446.	< 1	365.	594.	36.8 4.24	313.	18.		16.2	12.6	0.52	409.
14207232AAA2	84.5	24.7	21.5	8.0	79.2	0.985	1.14	10.2		7.00	< 1	468.	< 1	383.	875.	116. < 0.05	300.	18.		6.20	37.1	2.12	555.
14207418BCC	22.1	21.6	28.9	5.7	66.3	1.17	6.25	1.92		7.48	< 1	277.	< 1	227.	547.	87.4< 0.05	255.	15.		83.5	15.4	0.60	344.
14307129BBB2	11.1	22.4	28.6	7.1	80.8	0.635	2.87	3.22		7.33	< 1	319.	< 1	261.	546.	41.1< 0.05	294.	17.		79.7	7.3	0.28	325.
14307132CCC2	10.7	29.9	34.3	3.8	62.5	0.570	4.12	3.35		7.03	< 1	330.	< 1	270.	537.	37.2< 0.05	279.	16.		44.3	7.5	0.28	312.
14307229DCC2	17.0	22.9	22.4	4.6	70.0	1.02	0.298	2.86		7.51	< 1	328.	< 1	269.	563.	43.7< 0.05	269.	16.		11.4	11.8	0.45	325.
14407222AABC2	144.	29.9	26.8	21.1	102.	0.486	6.06	7.17		7.44	< 1	625.	< 1	512.	1220	222. < 0.05	378.	22.		67.8	43.5	3.22	836.
MINIMUM	2.0	14.3	17.5	2.4	25.6	< 0.002	< 0.007	0.57	0.17	6.70	< 1	232.	< 1	190.	353.	2.8< 0.05	170.	10.		< 1	1.4	0.05	216.
MAXIMUM	454.	131.	66.2	41.0	146.	6.14	28.4	267.	0.34	7.86	< 1	1350	< 1	1110	2580	415. 11.9	720.	42.		864.	77.0	11.0	1750
MEAN	41.5	31.5	29.7	6.6	84.9	1.001	3.76	9.7	0.26	7.09	0.5	411	0.5	337	775.6	99 0.83	341	20		58	16.4	1.1	483
MEDIAN	16.6	27.1	28.0	4.7	83.2	0.884	2.37	3.7	0.26	7.02	0.5	363	0.5	297	695.5	79 0.01	320	19		26	9.9	0.4	422
STDDEV	71.3	19.0	9.0	5.4	22.5	0.767	4.72	28.3	0.12	0.24	0.0	154	0.0	126	329.8	70 2.51	103	6		108	17.4	1.8	223

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption Ratio). CaCO3 is total hardness measured as calcium carbonate.

***** MILNOR CHANNEL AQUIFER *****

WELL_ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
12905022AADC	73.5	77.9	31.0	11.5	258.	0.287	3.17	10.0		6.97	< 1	533.	< 1	437.	1850	751. < 0.05	966.	56.		27.7	14.0	1.03	1450
12905026DDC	80.9	73.2	30.7	12.4	214.	0.431	3.43	10.1		6.91	< 1	507.	< 1	415.	1680	637. < 0.05	836.	49.		30.7	17.0	1.22	1280
13005003CAB	1.8	16.5	32.8	2.8	79.9	0.556	0.619	8.43		6.80	< 1	317.	< 1	260.	515.	25.7< 0.05	268.	16.		6.50	1.4	0.05	293.
13005007AAA	3.0	19.7	32.2	2.7	86.8	0.654	1.47	5.47		6.99	< 1	363.	< 1	297.	579.	20.4< 0.05	298.	17.		16.6	2.1	0.08	319.
13005010CCC	14.9	47.5	31.2	6.8	140.	0.425	1.22	1.91		6.87	< 1	454.	< 1	372.	1010	245. < 0.05	545.	32.		10.4	5.5	0.28	682.
13005010CCC	13.9	49.6	40.1	7.4	157.	0.450	7.12	1.35		7.08	< 1	426.	< 1	349.	1000	240. < 0.05	597.	35.	100.		4.7	0.25	681.
13005017DDD	29.9	108.	32.7	13.0	106.	0.365	1.72	6.25		6.80	< 1	515.	< 1	422.	1250	346. 0.05	709.	41.		16.2	8.2	0.49	865.
13005018DDD	39.9	95.7	30.8	14.2	151.	0.250	0.465	6.73		7.18	< 1	543.	< 1	445.	1420	444. 0.11	771.	45.		3.90	9.9	0.62	1020
13005022DCD	34.0	52.7	59.2	8.0	189.	1.08	11.1	6.84		7.10	< 1	388.	< 1	318.	1210	408. < 0.05	689.	40.	289.		9.5	0.56	892.
13005035CCC	28.2	62.6	32.4	7.5	208.	0.480	2.73	5.04		6.69	< 1	485.	< 1	397.	1420	464. < 0.05	778.	45.		18.1	7.2	0.44	1020
13005036CDD3	5.9	32.0	34.6	5.7	74.8	0.457	0.652	2.96		6.78	< 1	330.	< 1	270.	574.	61.9< 0.05	319.	19.		9.30	3.8	0.14	348.
13005106CCC	35.8	45.9	33.9	13.6	157.	0.886	2.31	28.0		6.82	< 1	493.	< 1	404.	1190	268. < 0.05	581.	34.		19.2	11.5	0.65	793.
13005108BBB	230.	46.9	41.0	18.6	193.	1.14	3.05	23.4	0.16	6.80	< 1	636.	< 1	521.	2070	685. < 0.05	675.	39.		25.1	41.6	3.85	1510
13005109ABD	150.	59.3	39.8	18.2	220.	1.11	1.77	15.9	0.14	6.75	< 1	585.	< 1	479.	1940	681. 0.22	794.	46.		11.7	28.4	2.31	1440
13005202DDD	58.8	46.7	34.3	12.8	137.	0.969	0.256	12.6		6.85	< 1	500.	< 1	410.	1240	317. 0.26	535.	31.		1.56	18.8	1.11	834.
13005208DAD	196.	49.4	35.3	17.0	196.	1.41	1.09	21.1		6.83	< 1	590.	< 1	483.	1990	690. < 0.05	693.	40.		4.20	37.2	3.24	1460
13005211ADA	69.2	48.6	30.6	16.8	202.	1.32	1.86	181.		6.91	< 1	399.	< 1	327.	1620	335. < 0.05	705.	41.		14.6	17.1	1.13	1050
13005217BB	188.	43.8	32.0	15.3	189.	1.37	1.61	21.0		6.79	< 1	596.	< 1	488.	1930	662. < 0.05	653.	38.		9.66	37.7	3.20	1410
13005311DDD	243.	35.9	28.4	13.5	153.	1.10	0.854	62.3		6.91	< 1	611.	< 1	500.	1950	562. < 0.05	530.	31.		6.83	49.0	4.59	1370
13105124CBA	15.4	36.0	44.8	9.3	112.	0.735	0.405	3.11		6.74	< 1	333.	< 1	273.	783.	172. 0.06	428.	25.		3.20	7.0	0.32	514.
13105136BBC	13.5	25.9	28.8	6.8	108.	1.01	1.88	55.5		6.79	< 1	337.	< 1	276.	809.	88.4< 0.05	377.	22.		18.3	7.0	0.30	466.
13105136BBC	14.9	26.3	25.7	7.1	110.	1.03	1.86	61.8		7.25	< 1	314.	< 1	257.	806.	78.5< 0.05	383.	22.		15.8	7.6	0.33	455.
13105302CCB	103.	28.5	34.4	7.5	107.	0.699	0.411	25.0		7.00	< 1	476.	< 1	390.	1130	231. < 0.05	385.	22.		1.85	36.1	2.28	739.
13105303DDD2	11.8	38.0	28.4	3.1	118.	0.475	4.70	20.0		7.01	< 1	353.	< 1	289.	853.	185. 0.10	451.	26.		62.7	5.3	0.24	552.
13105305DAD	171.	39.0	28.9	4.7	155.	0.903	0.535	103.		6.91	< 1	497.	< 1	407.	1650	399. < 0.05	548.	32.		5.60	40.1	3.18	1120
13105307DAA	192.	30.9	34.6	13.6	131.	0.981	0.435	45.0		6.98	< 1	573.	< 1	469.	1600	395. < 0.05	455.	27.		2.64	46.8	3.92	1090
13105310DDC	139.	29.0	33.4	12.2	120.	0.800	0.870	26.2		7.01	< 1	513.	< 1	420.	1340	315. < 0.05	419.	24.		2.52	40.9	2.95	896.
13105311CCB	131.	30.3	35.1	8.9	110.	0.768	0.963	27.6		6.86	< 1	509.	< 1	417.	1230	269. < 0.05	400.	23.		8.00	40.8	2.85	830.
13105313BCC	60.3	50.7	39.5	13.4	185.	1.28	1.65	30.9		6.73	< 1	539.	< 1	441.	1350	344. < 0.05	671.	39.		13.5	15.9	1.01	952.
13105314CAD	19.2	26.1	25.4	3.6	94.5	0.369	< 0.007	7.73		6.84	< 1	370.	< 1	303.	723.	93.3 3.16	344.	20.	< 1		10.7	0.45	443.
13105323BBB	177.	25.7	32.8	12.4	101.	0.804	1.03	43.2		7.00	< 1	529.	< 1	433.	1440	324.	358.	21.		3.25	50.6	4.07	946.
13205323CCD	178.	222.	38.2	19.7	340.	1.17	2.60	283.	0.24	6.76	< 1	531.	< 1	435.	3360	1440 < 0.05	1760	103.		29.5	17.7	1.84	2750
13205326BBB	180.	214.	30.8	21.8	393.	1.82	0.975	364.	0.31	6.75	< 1	535.	< 1	438.	3620	1510 0.30	1860	109.		8.40	17.1	1.81	2950
13205331DDD	13.9	26.7	33.6	2.9	99.2	0.463	1.70	9.73		6.89	< 1	385.	< 1	315.	676.	75.0< 0.05	358.	21.		20.3	7.7	0.32	419.
13205336BBC	64.4	29.9	6.98	15.1	62.8	0.045	5.78	16.6		6.83	< 1	387.	< 1	317.	777.	107. 0.07	280.	16.	1030		31.8	1.67	489.
13205405BBB2	7.9	38.0	49.2	4.7	115.	1.80	7.51	14.7		6.82	< 1	315.	< 1	258.	748.	141. < 0.05	444.	26.		141.	3.7	0.16	479.
13205408AAD	16.0	30.5	30.3	3.6	93.4	0.295	0.739	6.89		6.85	< 1	344.	< 1	282.	723.	116. < 0.05	359.	21.		4.80	8.7	0.37	438.
13205409CBC	259.	95.4	29.3	10.3	173.	0.605	2.26	180.	0.34	7.14	< 1	702.	< 1	575.	2440	642. < 0.05	825.	48.		19.7	40.1	3.92	1710
13205409CBC	178.	109.	33.8	10.7	205.	0.593	2.25	142.		7.24	< 1	662.	< 1	542.	2240	584. < 0.05	961.	56.		20.5	28.3	2.50	1560
13205425DDD	26.5	25.3	30.5	2.9	86.7	0.363	1.06	6.57		7.06	< 1	349.	< 1	286.	693.	101. < 0.05	321.	19.		9.23	15.0	0.64	423.
13205429DDD	41.5	45.0	36.5	6.5	148.	0.948	1.57	38.6		6.98	< 1	460.	< 1	377.	1150	254. < 0.05	555.	32.		15.1	13.7	0.77	762.
13205501CDD	413.	19.4	30.4	13.9	72.3	0.234	0.380	78.7	0.60	7.10	< 1	413.	< 1	338.	2320	798. < 0.05	261.	15.		5.20	76.3	11.1	1600
13305402ACA	15.8	41.7	30.7	8.3	138.	1.41	3.48	85.5		6.61	< 1	382.	< 1	313.	1050	155. < 0.05	517.	30.		18.0	6.1	0.30	635.
13305403BCC2	13.7	30.8	28.9	4.7	102.	0.535	0.446	10.5		6.76	< 1	306.	< 1	251.	742.	165. < 0.05	382.	22.		5.00	7.1	0.30	480.
13305404CDD4	21.0	25.5	50.8	5.1	82.5	1.00	10.7	6.78		6.80	< 1	268.	< 1	219.	598.	100. < 0.05	311.	18.		98.2	12.5	0.52	375.
13305406CCB2	62.7	17.1	33.2	7.0	60.2	0.696	0.886	7.43		6.98	< 1	384.	< 1	314.	675.	70.9< 0.05	221.	13.		16.3	37.1	1.83	417.

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption Ratio). CaCO3 is total hardness measured as calcium carbonate.

*** MILNOR CHANNEL AQUIFER (continued) ***

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
13305407AAA	12.6	27.7	40.2	5.2	53.6	0.462	20.9	4.78		6.74	< 1	264.	< 1	216.	485.	54.0	< 0.05	248.	14.	242.	9.7	0.35	290.
13305407BAA2	4.4	30.0	30.4	3.1	103.	0.498	0.410	9.68		6.77	< 1	354.	< 1	290.	713.	120.	< 0.05	381.	22.	4.80	2.4	0.10	447.
13305409DDD2	47.1	51.4	43.0	5.9	129.	0.674	4.63	14.7		6.81	< 1	461.	< 1	378.	1050	246.	< 0.05	534.	31.	86.1	15.8	0.89	723.
13305414BBC	180.	8.3	28.5	8.4	33.8	0.184	0.202	29.0		7.00	< 1	450.	< 1	369.	997.	146.	< 0.05	119.	7.	< 1	75.1	7.18	629.
13305416DCC	162.	5.9	37.0	7.0	22.0	0.237	2.45	30.8		7.50	< 1	439.	< 1	360.	854.	66.5	< 0.05	79.	5.	92.0	79.9	7.91	513.
13305416DDD	189.	33.4	26.4	6.3	50.4	0.190	6.92	28.5		7.04	< 1	503.	< 1	412.	1280	279.	< 0.05	263.	15.	48.2	60.1	5.06	836.
13305418CCC	11.9	27.5	29.4	3.7	84.8	0.209	0.715	8.00		6.91	< 1	301.	< 1	247.	613.	95.4	0.08	325.	19.	1.96	7.2	0.29	382.
13305419CCC	97.9	25.7	59.5	7.9	38.9	0.917	48.6	19.3		6.94	< 1	307.	< 1	251.	877.	204.	< 0.05	203.	12.	892.	49.9	2.99	547.
13305420DCD2	30.9	15.8	75.2	6.6	74.1	1.58	20.0	4.61		6.87	< 1	334.	< 1	274.	559.	52.0	< 0.05	250.	15.	471.	20.5	0.85	351.
13305421DDD2	6.6	22.2	33.9	2.4	69.4	0.421	3.16	2.32		6.70	< 1	260.	< 1	213.	502.	72.5	< 0.05	265.	15.	34.8	5.1	0.18	306.
13305428BAA3	3.9	25.6	45.2	3.0	82.4	0.632	4.72	2.60		6.76	< 1	234.	< 1	192.	532.	102.	< 0.05	311.	18.	55.2	2.6	0.10	337.
13305430DDD	13.4	25.2	67.5	3.3	90.1	1.13	12.5	14.4		6.85	< 1	285.	< 1	233.	626.	97.9	< 0.05	329.	19.	257.	8.0	0.32	387.
13305431BBB	46.0	57.3	52.8	11.5	170.	2.11	13.6	47.6		6.72	< 1	296.	< 1	242.	1260	400.	< 0.05	661.	39.	231.	12.8	0.78	880.
13305433BAA2	5.8	31.2	37.6	3.1	122.	0.630	3.89	32.6		6.76	< 1	265.	< 1	217.	827.	196.	< 0.05	433.	25.	59.5	2.8	0.12	523.
13305434DCC	26.3	33.4	31.5	4.9	112.	0.541	1.57	24.0		6.91	< 1	365.	< 1	299.	868.	167.	< 0.05	417.	24.	15.9	11.8	0.56	549.
13305436CDD	20.9	35.1	31.6	6.4	79.9	0.134	1.88	11.7		6.98	< 1	443.	< 1	363.	733.	50.9	< 0.05	344.	20.	19.8	11.4	0.49	425.
13305522ABA	92.9	90.6	29.8	11.9	248.	0.674	0.678	21.8	0.22	6.80	< 1	588.	< 1	482.	2000	708.	3.75	993.	58.	3.50	16.6	1.28	1480.
13305525AAD	199.	12.5	28.8	8.6	46.9	0.312	0.129	32.6		7.26	< 1	431.	< 1	353.	1200	278.	< 0.05	169.	10.	< 1	70.6	6.66	792.
MINIMUM	1.8	5.9	6.98	2.4	22.0	0.045	< 0.007	1.35	0.14	6.61	< 1	234.	< 1	192.	485.	20.4	< 0.05	79.	5.	< 1	1.4	0.05	290.
MAXIMUM	413.	222.	75.2	21.8	393.	2.11	48.6	364.	0.60	7.50	< 1	702.	< 1	575.	3620	1510	3.75	1860	109.	1030	79.9	11.1	2950.
MEAN	81.1	45.8	35.6	8.8	130.4	0.752	3.92	38.6	0.29	6.90	0.5	431	0.5	353	1217.8	318	0.14	514	30	73	22.2	1.8	838
MEDIAN	40.7	33.4	32.8	7.5	112.0	0.685	1.71	18.0	0.24	6.86	0.5	429	0.5	357	1050.0	243	0.01	424	25	16	13.9	0.8	703
STDDEV	86.7	39.1	10.5	5.0	69.8	0.452	7.23	64.9	0.16	0.16	0.0	115	0.0	94	665.8	304	0.61	321	19	184	20.5	2.2	544

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption Ratio).
CaCO3 is total hardness measured as calcium carbonate.

*** SHEYENNE DELTA AQUIFER ***

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
13305106DDA	5.4	16.1	30.1	2.4	74.3	0.316	0.768	5.93		7.11	< 1	292.	< 1	239.	516.	48.2	< 0.05	252.	15.	5.60	4.4	0.15	298.
13305109BDD	18.2	26.0	31.4	5.2	83.6	0.318	3.62	1.22		7.17	< 1	473.	< 1	387.	680.	15.6	< 0.05	316.	18.	42.4	10.9	0.45	385.
13305118ABB	60.1	91.4	25.5	10.8	233.	0.954	3.69	116.		7.00	< 1	746.	< 1	611.	1910	362.	0.82	959.	56.	4.70	11.8	0.84	1250
13305118ABB	59.1	98.6	23.4	11.0	245.	1.06	3.71	143.		7.08	< 1	665.	< 1	545.	1920	388.	0.05	1020	59.	33.0	11.0	0.81	1270
13305130AAC	53.1	66.9	32.3	7.2	148.	0.379	2.53	49.1		7.20	< 1	654.	< 1	536.	1370	228.	0.26	645.	38.	34.7	14.9	0.91	878.
13305132BCB	52.9	69.8	31.2	11.6	245.	1.01	2.21	3.83		6.73	< 1	529.	< 1	433.	1680	631.	< 0.05	900.	53.	13.2	11.1	0.77	1280
13305311BBB2	5.7	25.0	34.5	4.0	86.0	0.557	11.1	2.96		6.80	< 1	416.	< 1	341.	573.	8.6	< 0.05	318.	19.	180.	3.7	0.14	339.
13305311BBB2	7.2	26.8	47.4	4.4	96.5	1.14	13.4	2.70		7.27	< 1	391.	< 1	320.	614.	10.4	< 0.05	352.	21.	266.	4.2	0.17	343.
13305317ADD	17.0	77.8	31.9	7.2	268.	1.09	11.6	158.		6.83	< 1	666.	< 1	545.	1810	347.	< 0.05	990.	58.	105.	3.6	0.23	1210
13305401ABCCBD	5.7	58.8	47.6	< 1	155.	1.99	10.7	45.2		7.27	< 1	450.	< 1	369.	943.	119.	< 0.05	629.	37.	87.6	1.9	0.10	608.
13305412BBB2	8.0	24.0	30.2	3.4	88.6	0.555	4.23	5.75		6.88	< 1	313.	< 1	256.	648.	109.	< 0.05	320.	19.	70.0	5.1	0.19	395.
13405118CCC	39.4	55.8	33.9	7.7	119.	0.538	4.73	102.		6.84	< 1	571.	< 1	468.	1150	59.2	< 0.05	527.	31.	40.8	13.7	0.75	666.
13405120AAA	113.	105.	24.6	25.3	190.	0.810	0.392	72.7		6.87	< 1	809.	< 1	663.	1960	476.	1.37	907.	53.	4.50	20.7	1.63	1390
13405120AAA	113.	103.	21.5	24.5	183.	0.827	4.24	78.5		7.00	< 1	757.	< 1	620.	1910	433.	0.85	881.	51.	27.2	21.1	1.65	1310
13405132BBB	15.4	26.9	31.4	7.6	106.	0.604	0.465	1.37		6.89	< 1	537.	< 1	440.	741.	20.5	< 0.05	376.	22.	5.60	8.0	0.35	444.
13405202ABC	48.2	77.0	34.3	10.6	264.	1.33	7.62	103.		6.84	< 1	862.	< 1	706.	1820	257.	< 0.05	977.	57.	66.6	9.5	0.67	1190
13405202ABC	51.7	72.6	32.2	10.8	252.	1.27	7.63	78.0		6.90	< 1	790.	< 1	647.	1710	263.	< 0.05	929.	54.	78.4	10.6	0.74	1120
13405204BAA2	7.6	21.3	39.2	6.2	89.5	0.845	7.41	0.70		7.06	< 1	437.	< 1	358.	622.	11.7	< 0.05	311.	18.	74.0	4.9	0.19	354.
13405221CDDCDB1	10.3	38.8	22.7	1.0	63.6	0.873	0.418	7.73		7.06	< 1	432.	< 1	354.	620.	17.8	< 0.05	319.	19.	13.5	6.5	0.25	354.
13405236CCC	24.9	29.5	28.2	2.8	102.	0.612	1.06	63.0		7.30	< 1	369.	< 1	302.	806.	52.0	0.98	376.	22.	4.26	12.4	0.56	462.
13405304AABAAB1	0.6	10.3	30.4	< 1	56.5	1.14	3.61	2.58		6.81	< 1	196.	< 1	161.	340.	27.9	< 0.05	184.	11.	25.5	0.7	0.02	198.
13405312BBB2	20.5	38.5	31.1	5.8	77.2	0.116	7.43	3.48		6.94	< 1	491.	< 1	402.	721.	18.8	< 0.05	351.	21.	76.0	11.0	0.48	408.
13405312BBB2	21.4	41.0	42.4	6.4	88.9	0.499	13.5	3.48		7.42	< 1	465.	< 1	381.	731.	19.8	< 0.05	391.	23.	107.	10.4	0.47	412.
13405314DCCCCC1	12.8	59.0	20.7	6.8	58.7	17.1	5.26	9.59		6.68	< 1	451.	< 1	369.	941.	13.9	< 0.05	390.	23.	35.0	6.5	0.28	385.
13405314DCCCCC1	10.6	35.4	25.2	6.1	36.9	9.13	6.07	7.20		7.12	< 1	315.	< 1	258.	501.	7.8	< 0.05	238.	14.	39.0	8.5	0.30	261.
13405402DDDDDD1	1.9	22.5	14.4	< 1	77.0	0.284	1.96	2.53		6.96	< 1	316.	< 1	259.	537.	13.1	9.44	285.	17.	9.80	1.4	0.05	318.
13405404AAA	11.8	22.5	33.5	3.2	82.8	0.284	4.54	5.66		6.81	< 1	358.	< 1	293.	595.	49.7	< 0.05	300.	17.	42.0	7.8	0.30	354.
13405409AAA2	13.5	24.5	37.3	3.7	92.3	0.439	16.2	2.40		6.82	< 1	413.	< 1	338.	637.	44.3	< 0.05	332.	19.	129.	8.0	0.32	386.
13405421AAA	24.4	44.1	27.9	9.2	122.	0.682	2.22	66.1		6.83	< 1	401.	< 1	328.	1010	160.	< 0.05	486.	28.	28.4	9.6	0.48	625.
13405436CCC2	2.0	24.6	25.4	1.6	97.5	0.633	3.03	6.36		6.85	< 1	313.	< 1	256.	665.	120.	< 0.05	345.	20.	39.0	1.2	0.05	408.
13505018DED	48.7	31.9	31.2	9.6	138.	0.553	1.07	2.17		6.80	< 1	517.	< 1	423.	1060	215.	< 0.05	476.	28.	7.60	17.7	0.97	702.
13505110CCBBBB1	159.	986.	37.4	13.5	234.	0.080	3.72	14.0		7.28	< 1	726.	< 1	595.	5500	3840	0.11	4640	271.	31.0	6.9	1.01	5610
13505119DAAAAA1	11.9	55.9	32.7	19.1	123.	0.925	4.26	12.6		6.94	< 1	673.	< 1	551.	982.	45.8	< 0.05	538.	31.	55.0	4.4	0.22	602.
13505119DAAAAA1	11.8	55.7	35.6	24.2	122.	1.03	3.89	10.6		7.17	< 1	623.	< 1	510.	725.	40.5	< 0.05	534.	31.	45.0	4.3	0.22	574.
13505134BCCCCB1	50.4	80.2	34.8	1.4	168.	0.592	4.62	5.96		7.02	< 1	739.	< 1	605.	1390	244.		750.	44.	66.0	12.7	0.80	916.
13505134BCCCCB1	26.8	63.6	32.0	1.6	135.	0.413	1.39	1.25		7.24	< 1	553.	< 1	453.	1030	154.	< 0.05	599.	35.	16.0	8.8	0.48	657.
13505204BDBBBD	6.5	30.1	38.9	1.7	80.7	1.00	5.47	5.99		6.94	< 1	401.	< 1	328.	631.	33.0	< 0.05	326.	19.	67.0	4.1	0.16	358.
3505204BDBBBD	6.6	32.1	38.8	1.8	85.6	1.08	5.34	5.88		7.42	< 1	375.	< 1	307.	625.	32.4	< 0.05	346.	20.	61.0	3.9	0.15	351.
13505210ACA2	4.5	18.9	27.1	5.8	79.7	0.257	5.72	1.40		7.18	< 1	279.	< 1	229.	441.	30.0	0.11	277.	16.	606.	3.3	0.12	280.
13505210ACA2	4.4	15.2	74.5	4.0	73.2	1.64	24.8	0.81		7.51	< 1	276.	< 1	226.	437.	12.7	0.05	246.	14.	1610	3.7	0.12	248.
13505221CCC	5.9	22.9	29.7	2.3	78.7	0.294	7.26	0.44		6.91	< 1	412.	< 1	337.	602.	8.9	< 0.05	291.	17.	100.	4.2	0.15	324.
13505225AAABAA	33.6	30.1	37.7	6.4	108.	1.83	8.02	1.57		6.94	< 1	455.	< 1	373.	706.	58.5	< 0.05	394.	23.	67.0	15.3	0.74	464.
13505227CCC2	17.4	30.7	33.5	3.6	116.	0.651	6.11	0.56		7.00	< 1	577.	< 1	473.	808.	14.2	< 0.05	416.	24.	59.0	8.2	0.37	469.
13505227CCC2	18.8	30.8	33.0	3.8	119.	0.643	5.74	0.45		7.24	< 1	548.	< 1	449.	783.	11.3	< 0.05	424.	25.	61.0	8.7	0.40	456.
13505233DAAAAA1	41.6	45.9	36.1	6.0	110.	0.429	5.12	7.86		6.84	< 1	589.	< 1	482.	903.	54.8	< 0.05	464.	27.	52.0	16.0	0.84	558.
13505233DAAAAA1	25.8	41.3	37.7	6.0	94.9	0.381	3.90	4.95		7.24	< 1	502.	< 1	411.	781.	30.9	< 0.05	407.	24.	40.0	11.9	0.56	453.
13505316BBAB	5.1	24.3	88.2	< 1	98.4	3.54	21.9	3.51		6.92	< 1	437.	< 1	358.	605.	16.8	< 0.05	346.	20.	664.	3.1	0.12	366.
13505316DDD	12.7	26.9	29.7	4.3	93.7	0.432	5.44	3.56		7.06	< 1	517.	< 1	423.	738.	8.6	< 0.05	345.	20.	69.0	7.3	0.30	407.
13505317AAC	13.7	47.0	36.7	2.4	191.	0.014	0.099	48.7		6.82	< 1	525.	< 1	430.	1250	166.	17.4	671.	39.	< 1	4.2	0.23	807.

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption Ratio). CaCO3 is total hardness measured as calcium carbonate.

***** SHEYENNE DELTA AQUIFER (continued) *****

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WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
13505321BBAB2	5.1	35.1	36.5	2.2	161.	1.95	15.5	53.5		6.62	< 1	401.	< 1	328.	975.	176. < 0.05	547.	32.	94.0	2.0	0.09	633.	
13505322CCC	9.0	27.3	30.6	3.9	96.0	0.361	6.98	4.38		7.02	< 1	496.	< 1	406.	728.	10.9< 0.05	352.	21.	82.0	5.2	0.21	398.	
13505328BBBADB1	1.3	18.8	37.1	< 1	71.2	0.634	23.7	1.05		6.99	< 1	323.	< 1	265.	453.	5.8< 0.05	255.	15.	120.	1.1	0.04	260.	
13505330BBB	9.5	23.3	29.9	3.5	91.9	0.240	10.9	0.72		6.92	< 1	420.	< 1	344.	605.	3.8< 0.05	326.	19.	137.	5.9	0.23	342.	
13505401CCCCC1	1.3	12.1	26.1	< 1	62.8	0.041	0.353	1.47		6.80	< 1	267.	< 1	219.	399.	11.3< 0.05	207.	12.	< 1	1.3	0.04	224.	
13505416ACDDDD1	2.2	20.3	32.7	2.2	83.6	0.639	2.86	5.44		6.91	< 1	304.	< 1	249.	541.	57.1< 0.05	293.	17.	37.0	1.6	0.06	323.	
13505429DAAAAA	0.4	24.5	26.0	< 1	97.8	0.587	0.980	1.75		6.93	< 1	442.	< 1	362.	591.	9.4< 0.05	345.	20.	9.00	0.2	0.01	355.	
13605110CCD	3.3	20.3	26.4	1.1	87.3	0.481	1.32	12.8		6.61	< 1	213.	< 1	174.	584.	127. 3.66	302.	18.	7.40	2.3	0.08	375.	
13605110CCD	3.4	19.9	25.6	1.2	85.2	0.520	1.59	11.3		7.08	< 1	189.	< 1	155.	559.	114. 1.74	295.	17.	6.50	2.4	0.09	338.	
13605115ABBCBB2	2.6	23.0	42.3	2.2	88.1	1.05	5.90	8.35		6.68	< 1	245.	< 1	201.	566.	110. < 0.05	315.	18.	98.4	1.7	0.06	357.	
13605119DCD	4.8	30.5	25.1	2.0	82.8	0.110	0.099	5.81		6.99	< 1	400.	< 1	328.	736.	31.8 3.77	333.	19.	3.30	3.0	0.11	374.	
13605124DADDAB1	31.5	42.5	23.1	2.4	147.	1.37	2.14	199.		7.00	< 1	406.	< 1	333.	1210	40.9 0.09	542.	32.	21.0	11.1	0.59	666.	
13605125BCCCCC1	24.2	35.0	34.0	5.9	70.1	1.12	8.11	7.56		6.80	< 1	396.	< 1	324.	678.	59.5< 0.05	319.	19.	66.0	13.8	0.59	399.	
13605131ADBDBA1	7.5	17.8	37.8	4.4	74.9	0.643	9.86	2.80		6.90	< 1	305.	< 1	250.	467.	15.6< 0.05	260.	15.	92.0	5.7	0.20	275.	
13605132BCD	20.2	21.0	36.0	8.2	87.3	0.412	2.06	6.08		6.82	< 1	448.	< 1	367.	649.	27.6< 0.05	305.	18.	20.5	12.2	0.50	393.	
13605132BCD	20.0	21.2	33.3	8.2	88.0	0.424	2.09	6.02		7.14	< 1	400.	< 1	328.	657.	26.6< 0.05	307.	18.	8.10	12.0	0.50	369.	
13605132CCCCC1	2.6	36.2	50.6	4.8	120.	1.03	9.45	7.40		6.92	< 1	416.	< 1	341.	678.	42.6< 0.05	449.	26.	110.	1.2	0.05	421.	
13605136AA	46.9	35.4	32.1	10.3	145.	0.562	1.43	1.34		6.73	< 1	529.	< 1	433.	1090	248. < 0.05	508.	30.	4.30	16.3	0.90	750.	
13605209ADDDDD1	33.0	53.7	33.5	8.5	103.	2.22	2.00	1.66		7.29	< 1	577.	< 1	473.	908.	46.3< 0.05	478.	28.	20.0	12.7	0.66	532.	
13605210ADD	36.5	46.5	24.6	7.9	151.	0.842	3.72	20.6		7.06	< 1	573.	< 1	469.	1120	138. < 0.05	569.	33.	38.5	12.0	0.67	685.	
13605210ADD2	72.5	79.5	19.5	21.7	226.	1.01	0.214	119.		6.88	< 1	767.	< 1	628.	1870	352. 4.88	892.	52.	3.90	14.6	1.06	1270	
13605212CBB	10.4	31.0	30.8	7.4	121.	0.377	4.31	0.83		6.90	< 1	603.	< 1	494.	821.	8.2< 0.05	430.	25.	52.2	4.9	0.22	478.	
13605212CBB	10.3	31.7	30.2	7.6	125.	0.380	4.52	0.64		7.18	< 1	554.	< 1	454.	807.	7.6< 0.05	443.	26.	52.5	4.7	0.21	458.	
13605214CBBCCD1	15.3	43.2	37.6	2.1	158.	1.73	5.88	15.4		6.86	< 1	662.	< 1	542.	1110	102. < 0.05	573.	33.	18.0	5.4	0.28	664.	
13605222ABB	9.9	40.9	30.8	2.3	145.	0.756	4.84	14.1		6.75	< 1	417.	< 1	342.	983.	230. < 0.05	531.	31.	17.3	3.9	0.19	650.	
13605222CCC	13.1	29.2	30.5	4.6	103.	0.681	8.32	0.78		7.06	< 1	532.	< 1	436.	754.	7.9< 0.05	378.	22.	93.8	6.9	0.29	423.	
13605222CCC	12.6	29.7	28.9	4.8	106.	0.752	8.60	0.65		7.20	< 1	488.	< 1	400.	712.	7.5< 0.05	387.	23.	97.0	6.5	0.28	404.	
13605226ABC	4.5	21.5	29.7	2.4	74.1	0.508	0.302	1.74		6.76	< 1	350.	< 1	287.	536.	25.9 0.51	274.	16.	5.80	3.4	0.12	307.	
13605228ABBBBB	2.4	15.8	21.2	< 1	77.5	0.144	0.685	1.58		6.90	< 1	250.	< 1	205.	490.	44.7 4.90	259.	15.	11.0	2.0	0.06	290.	
13605228ABBBBB	< 3	17.1	24.1	< 1	79.1	0.152	1.29	1.18		7.58	< 1	263.	< 1	215.	476.	43.0 0.49	268.	16.	25.0	2.4	0.08	278.	
13605229BBB	5.1	22.2	31.0	2.0	65.3	0.312	4.27	1.81		6.95	< 1	322.	< 1	264.	503.	27.8< 0.05	255.	15.	49.0	4.1	0.14	285.	
13605229DDD	6.3	18.6	80.1	5.3	75.8	1.76	32.6	1.09		6.93	< 1	349.	< 1	286.	486.	5.05 0.15	266.	16.	48.0	4.8	0.17	287.	
13605229DDD	5.7	19.8	28.2	4.1	78.4	0.458	4.24	0.60		7.43	< 1	341.	< 1	279.	506.	4.43<0.05	277.	16.	62.0	4.2	0.15	283.	
13605321DDDD2	7.9	21.5	28.9	2.8	72.1	0.304	13.9	0.74		6.78	< 1	378.	< 1	310.	535.	4.7< 0.05	269.	16.	86.6	5.9	0.21	298.	
13605326ABAAAA1	4.1	26.7	24.3	< 1	95.8	0.423	0.658	20.5		6.93	< 1	248.	< 1	203.	664.	152. 0.63	349.	20.	16.8	2.5	0.10	427.	
13605329AAA2	1.9	18.5	29.9	< 1	81.3	0.077	1.33	10.8		6.86	< 1	252.	< 1	206.	517.	68.7 0.20	279.	16.	20.0	1.4	0.05	309.	
13705217DDC	213.	14.5	30.7	8.9	47.9	0.109	0.517	96.5		7.11	< 1	445.	< 1	364.	1270	204. 0.18	179.	10.	6.30	70.7	6.91	807.	
13705217DDC	208.	14.4	27.8	8.6	47.1	0.108	0.456	89.9		7.58	< 1	403.	< 1	330.	1270	194. < 0.05	177.	10.	4.40	70.5	6.80	763.	
13705228CAA	39.0	34.7	32.3	8.3	131.	0.382	2.02	3.34		6.97	< 1	540.	< 1	442.	1040	165. < 0.05	470.	27.	18.4	14.9	0.78	649.	
13705228CAA	32.0	32.4	30.5	7.7	120.	0.419	2.63	2.81		7.27	< 1	494.	< 1	405.	967.	150. < 0.05	433.	25.	26.0	13.5	0.67	590.	
MINIMUM	0.4	10.3	14.4	< 1	36.9	0.014	0.099	0.44		6.61	< 1	189.	< 1	155.	340.	3.8< 0.05	177.	10.	< 1	0.2	0.01	198.	
MAXIMUM	213.	986.	88.2	25.3	268.	17.1	32.6	199.		7.58	< 1	862.	< 1	706.	5500	3840 17.4	4640	271.	1610	70.7	6.91	5610	
MEAN	25.6	47.5	33.0	5.7	114.1	1.003	5.64	22.8	.	7.00	0.5	461	0.5	377	914.4	141 0.60	481	28	79	8.7	0.5	588	
MEDIAN	11.9	30.1	31.2	4.4	96.0	0.592	4.24	5.7	.	6.94	0.5	437	0.5	358	726.5	45 0.01	352	21	40	5.9	0.3	408	
STDDEV	38.6	102.9	10.9	5.3	52.4	2.022	5.83	40.4	.	0.21	0.0	152	0.0	125	641.2	417 2.25	491	29	191	10.6	1.0	612	

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption Ratio).
CaCO3 is total hardness measured as calcium carbonate.

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APPENDIX C

Aquifer Maps Showing Sample Locations

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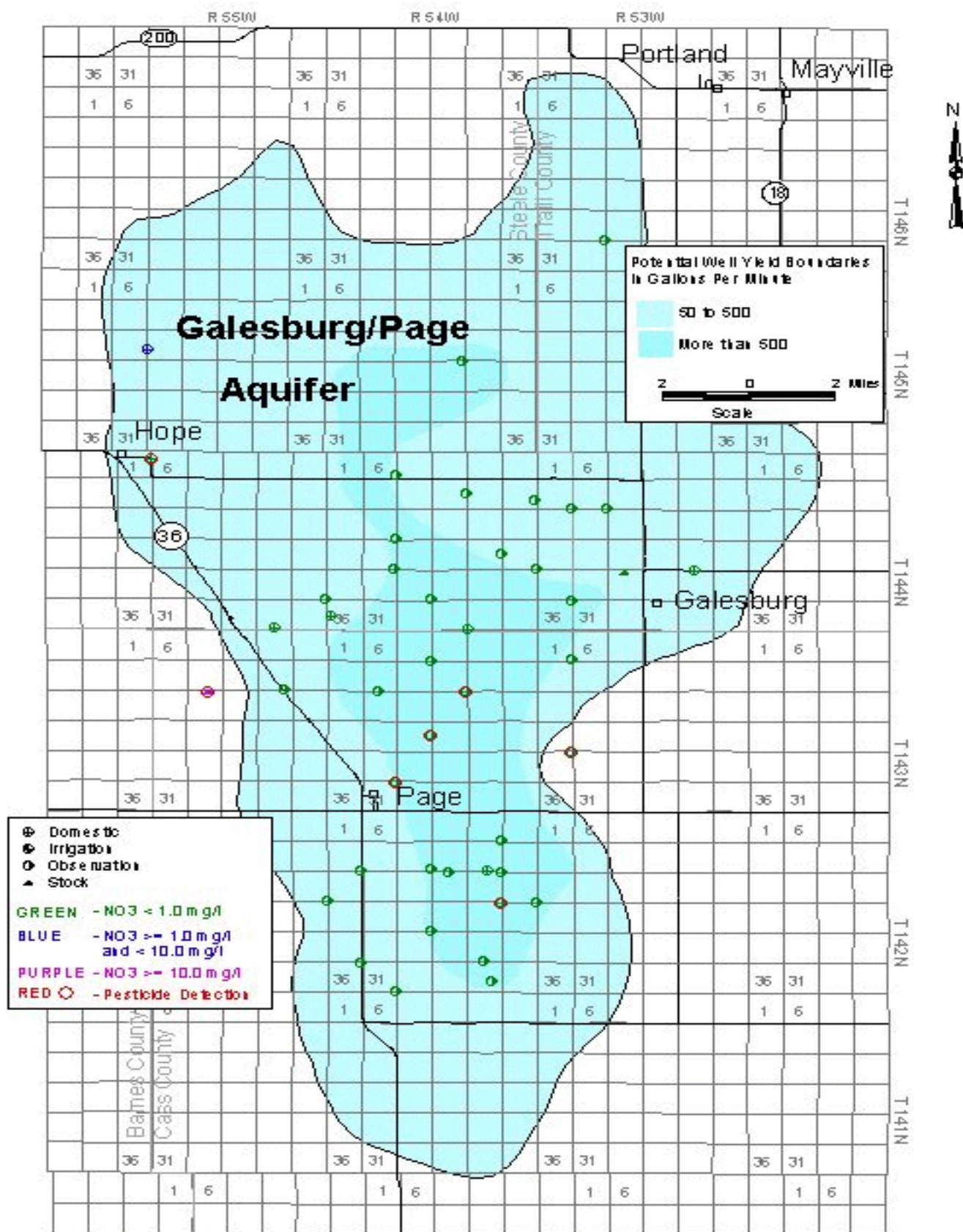


Figure C-1. Sample locations and areal extent for the Galesburg/Page aquifer

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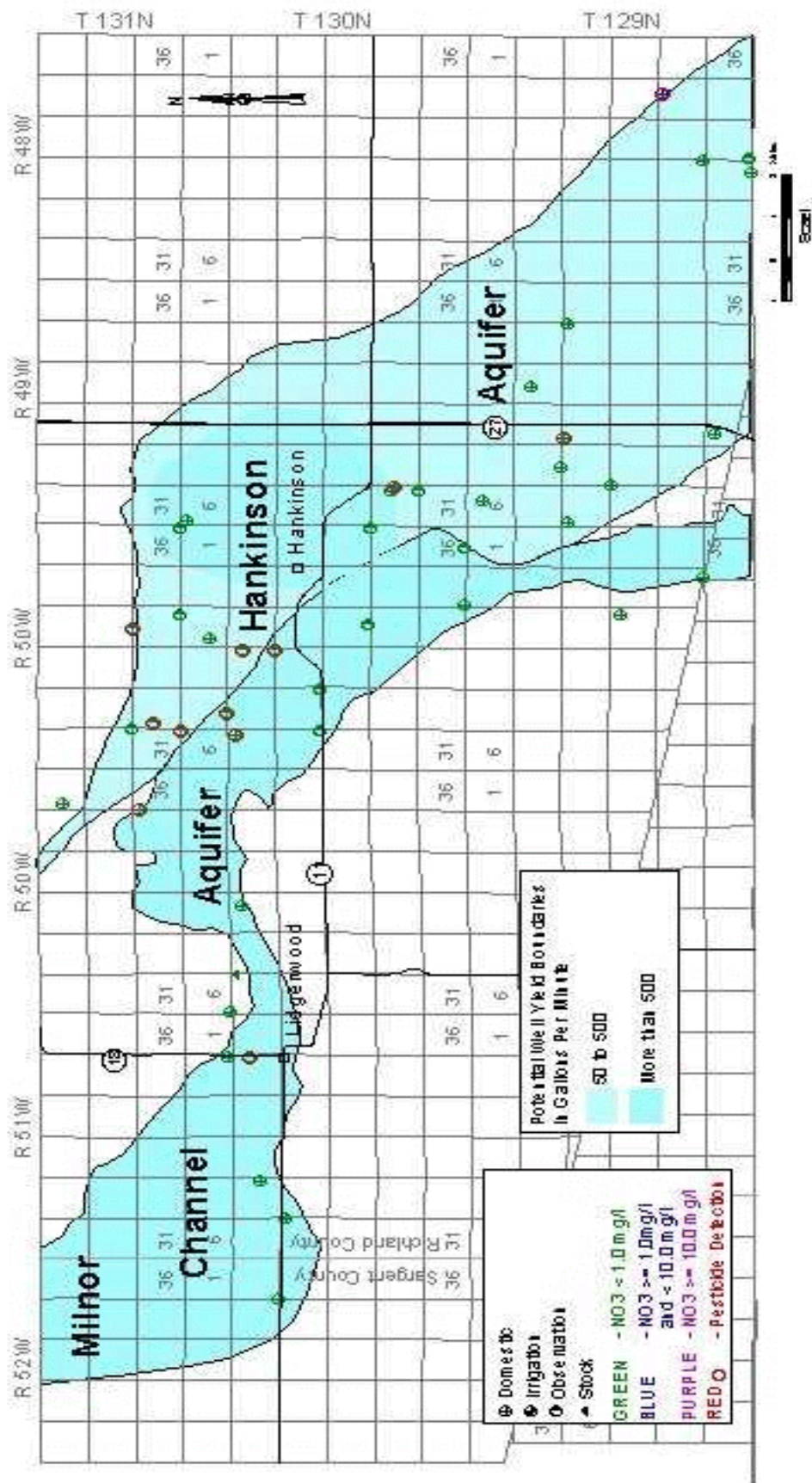


Figure C-2. Sample locations for the Hanson aquifer and the south half of the Milnor Channel aquifer

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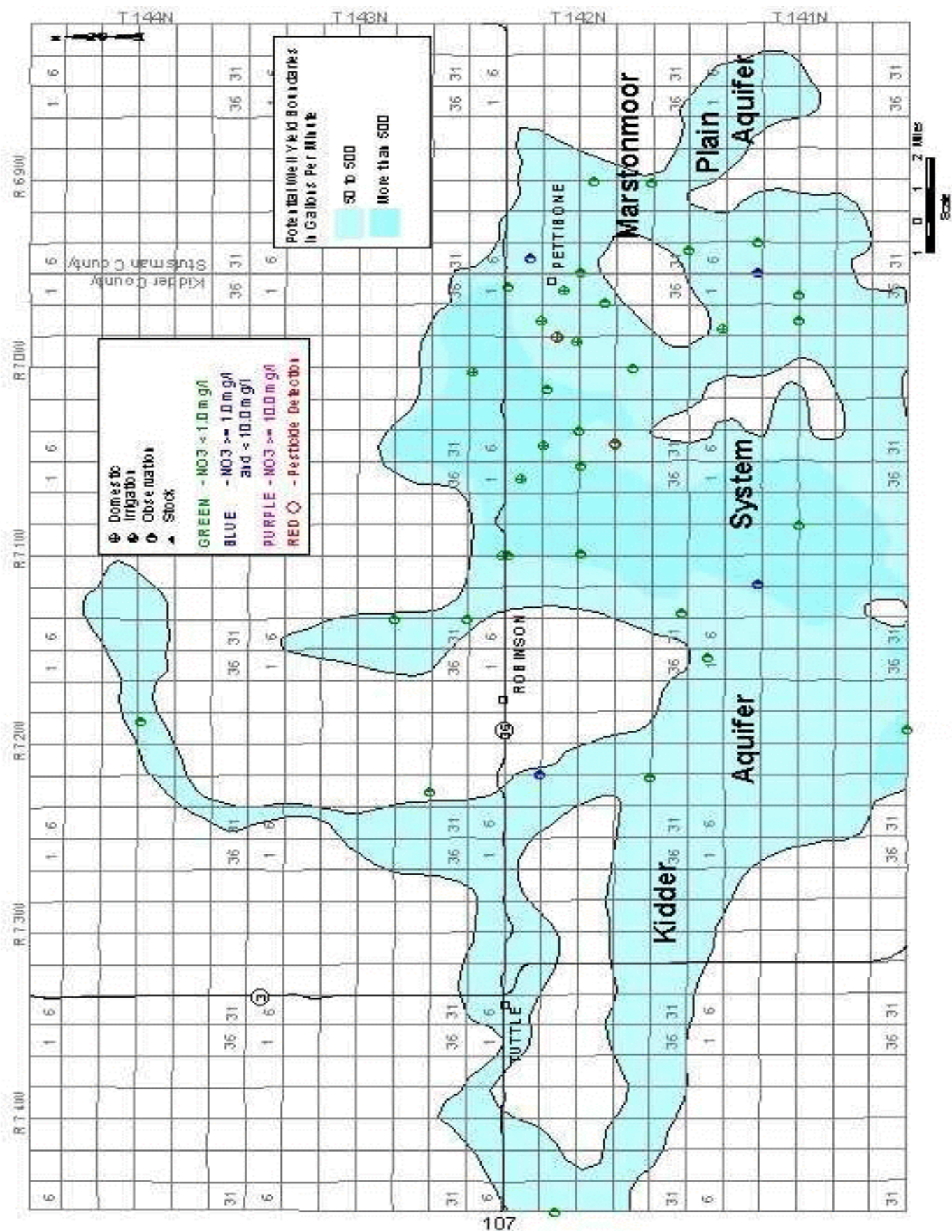


Figure C-3 Sample locations for the northern portion of the Kidder/Marstonmoor Plain aquifer

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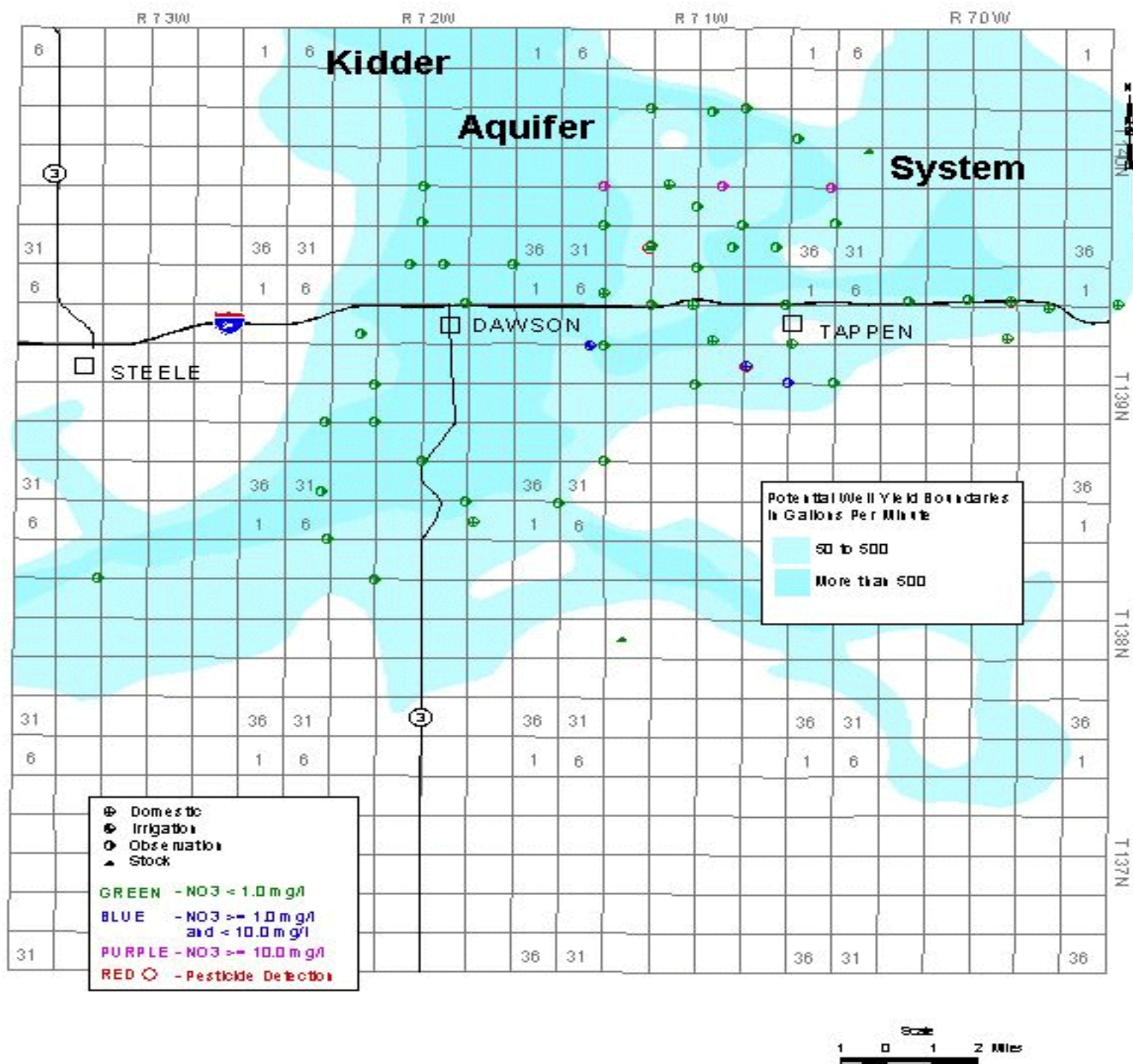


Figure C-4. Sample locations for the southern portion of the Kidder/Marstonmoor Plain aquifer

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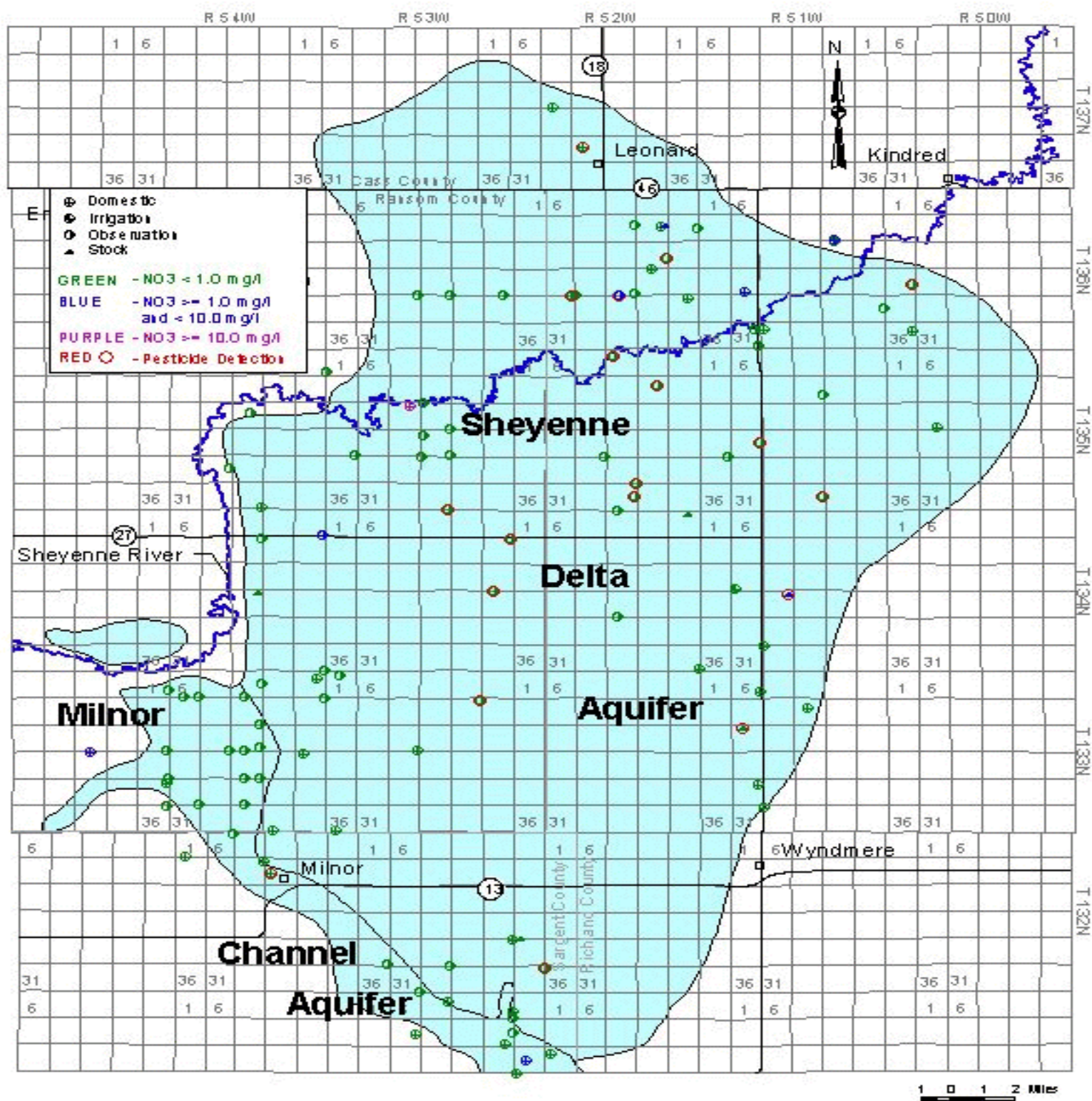


Figure C-5. Sample locations for the Sheyenne Delta aquifer and the north half of the Milnor Channel aquifer

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APPENDIX D

Summary Tables for Well-Construction and Site-Inventory Characteristics Related to Pesticide and Nitrate /Nitrite Detections for Each Aquifer

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Pesticide and Nitrate plus Nitrite Detections Related to Well Construction Galesburg/Page Aquifer

Wells with only pesticide detections : 4 8.7 %
Wells with only nitrate detections : 4 8.7 %
Wells with pesticide & nitrate detections : 3 6.5 %
Wells with nitrate > 10 mg/L : 1 2.2 %

Total number of wells in sample population : 46

DEPTH OF WELLS			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 20 Ft. :	0	0.0	0	0.0	*****	0	*****	
20 - 50 Ft. :	5	10.9	2	40.0	3	60.0		
> 50 Ft. :	41	89.1	5	12.2	4	9.8		
Unknown :	0	0.0	0	*****	0	*****		

DIAMETER OF WELL			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 6 in. :	43	93.5	6	14.0	5	11.6		
6 - 18 in. :	2	4.3	0	0.0	1	50.0		
> 18 in. :	1	2.2	1	100.0	1	100.0		
Unknown :	0	0.0	0	*****	0	*****		

CASING MATERIAL			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Plastic(PVC or ABS) :	41	89.1	5	12.2	5	12.2		
Concrete/Brick/Stone :	0	0.0	0	*****	0	*****		
Metallic :	5	10.9	2	40.0	2	40.0		
Other :	0	0.0	0	*****	0	*****		

DEPTH TO TOP OF SCREENED INTERVAL			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 20 Ft. :	2	4.3	2	100.0	1	50.0		
20 - 50 Ft. :	6	13.0	0	0.0	3	50.0		
> 50 Ft. :	38	82.6	5	13.2	3	7.9		
Unknown :	0	0.0	0	*****	0	*****		

DISTANCE FROM WATER TABLE TO TOP OF SCREEN			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 10 Ft. :	3	6.5	2	66.6	2	66.6		
10 - 30 Ft. :	4	8.7	0	0.0	2	50.0		
> 30 Ft. :	38	82.6	5	13.2	3	7.9		
Unknown :	1	2.2	0	0.0	0	0.0		

TYPE OF WELL			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Monitoring :	35	76.1	5	14.3	4	11.4		
Private/Domestic :	6	13.0	1	16.7	1	16.7		
Livestock :	3	6.5	1	33.3	1	33.3		
Public Supply :	2	4.3	0	0.0	1	50.0		
Irrigation :	0	0.0	0	*****	0	*****		
Other :	0	0.0	0	*****	0	*****		

Pesticide and Nitrate plus Nitrite Detections Related to Well Construction Hankinson Aquifer

Wells with only pesticide detections : 5 20.0 %
Wells with only nitrate detections : 3 12.0 %
Wells with pesticide & nitrate detections : 3 12.0 %
Wells with nitrate > 10 mg/L : 0 0.0 %

Total number of wells in sample population : 25

DEPTH OF WELLS			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 20 Ft. :	0	0.0	0	*****	0	*****		
20 - 50 Ft. :	16	64.0	6	37.5	4	25.0		
> 50 Ft. :	9	36.0	2	22.2	2	22.2		
Unknown :	0	0.0	0	*****	0	*****		

DIAMETER OF WELL			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 6 in. :	25	100.0	8	32.0	6	24.0		
6 - 18 in. :	0	0.0	0	*****	0	*****		
> 18 in. :	0	0.0	0	*****	0	*****		
Unknown :	0	0.0	0	*****	0	*****		

CASING MATERIAL			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Plastic(PVC or ABS) :	20	80.0	6	30.0	5	25.0		
Concrete/Brick/Stone :	0	0.0	0	*****	0	*****		
Metallic :	5	20.0	2	40.0	1	20.0		
Other :	0	0.0	0	*****	0	*****		

DEPTH TO TOP OF SCREENED INTERVAL			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 20 Ft. :	0	0.0	0	*****	0	*****		
20 - 50 Ft. :	18	72.0	6	33.3	4	22.2		
> 50 Ft. :	4	16.0	2	50.0	1	25.0		
Unknown :	3	12.0	0	0.0	1	33.3		

DISTANCE FROM WATER TABLE TO TOP OF SCREEN			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 10 Ft. :	0	0.0	0	*****	0	*****		
10 - 30 Ft. :	15	60.0	3	20.0	3	20.0		
> 30 Ft. :	7	28.0	4	57.1	2	28.6		
Unknown :	3	12.0	1	33.3	1	33.3		

TYPE OF WELL			#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Monitoring :	11	44.0	5	45.5	4	36.4		
Private/Domestic :	13	52.0	3	23.1	2	15.4		
Livestock :	1	4.0	0	*****	0	*****		
Public Supply :	0	0.0	0	*****	0	*****		
Irrigation :	0	0.0	0	*****	0	*****		
Other :	0	0.0	0	*****	0	*****		

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

Pesticide and Nitrate plus Nitrite Detections Related to Well Construction. Kidder/Marstonmoor Plain Aquifer

Wells with only pesticide detections : 4 4.5 %
Wells with only nitrate detections : 16 18.0 %
Wells with pesticide & nitrate detections : 1 1.1 %
Wells with nitrate > 10 mg/L : 3 3.4 %

Total number of wells in sample population : 89

DEPTH OF WELLS	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 20 Ft. :	1	1.1	0	0.0	1	100.0
20 - 50 Ft. :	39	43.8	1	2.6	11	28.2
> 50 Ft. :	49	55.1	4	8.2	5	10.2
Unknown :	0	0.0	0	*****	0	*****

DIAMETER OF WELL	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 6 in. :	88	98.9	5	5.7	17	19.3
6 - 18 in. :	0	0.0	0	*****	0	*****
> 18 in. :	1	1.1	0	0.0	0	0.0
Unknown :	0	0.0	0	*****	0	*****

CASING MATERIAL	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Plastic(PVC or ABS) :	80	89.9	4	5.0	16	20.0
Concrete/Brick/Stone :	0	0.0	0	*****	0	*****
Metallic :	8	9.0	1	12.5	1	12.5
Other :	1	1.1	0	0.0	0	0.0

DEPTH TO TOP OF SCREENED INTERVAL	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 20 Ft. :	4	4.5	0	0.0	3	75.0
20 - 50 Ft. :	41	46.1	3	7.3	10	24.4
> 50 Ft. :	42	47.2	2	0.5	4	9.5
Unknown :	2	2.2	0	0.0	0	0.0

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 10 Ft. :	8	9.0	1	12.5	3	37.5
10 - 30 Ft. :	40	44.9	4	10.0	14	35.0
> 30 Ft. :	36	40.4	0	0.0	0	0.0
Unknown :	5	5.6	0	0.0	0	0.0

TYPE OF WELL	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Monitoring :	69	77.5	1	1.4	15	21.7
Private/Domestic :	16	18.0	3	18.8	1	6.3
Livestock :	3	3.4	1	33.3	0	0.0
Public Supply :	0	0.0	0	*****	0	*****
Irrigation :	0	0.0	0	*****	0	*****
Other :	1	1.1	0	0.0	1	0.0

Pesticide and Nitrate plus Nitrite Detections Related to Well Construction Milnor Channel Aquifer

Wells with only pesticide detections : 5 8.2 %
Wells with only nitrate detections : 10 16.4 %
Wells with pesticide & nitrate detections : 1 1.6 %
Wells with nitrate > 10 mg/L : 0 0.0 %

Total number of wells in sample population : 61

DEPTH OF WELLS	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 20 Ft. :	2	3.3	0	0.0	1	50.0
20 - 50 Ft. :	30	49.2	5	16.7	5	16.7
> 50 Ft. :	29	47.5	1	3.4	5	17.2
Unknown :	0	0.0	0	*****	0	*****

DIAMETER OF WELL	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 6 in. :	61	100.0	6	9.8	11	18.0
6 - 18 in. :	0	0.0	0	*****	0	*****
> 18 in. :	0	0.0	0	*****	0	*****
Unknown :	0	0.0	0	*****	0	*****

CASING MATERIAL	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Plastic(PVC or ABS) :	55	90.2	6	10.9	10	18.2
Concrete/Brick/Stone :	0	0.0	0	*****	0	*****
Metallic :	6	9.8	0	0.0	1	16.6
Other :	0	0.0	0	*****	0	*****

DEPTH TO TOP OF SCREENED INTERVAL	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 20 Ft. :	5	8.3	1	20.0	1	20.0
20 - 50 Ft. :	39	65.0	4	10.3	6	15.4
> 50 Ft. :	17	27.9	1	5.9	4	23.5
Unknown :	0	0.0	0	*****	0	*****

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
< 10 Ft. :	4	6.6	0	0.0	2	50.0
10 - 30 Ft. :	30	49.2	3	10.0	5	16.7
> 30 Ft. :	22	36.1	2	9.1	3	13.6
Unknown :	5	8.2	1	20.0	1	20.0

TYPE OF WELL	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
Monitoring :	29	47.5	3	10.3	5	17.2
Private/Domestic :	30	49.2	3	10.0	6	20.0
Livestock :	2	3.3	0	0.0	0	0.0
Public Supply :	0	0.0	0	*****	0	*****
Irrigation :	0	0.0	0	*****	0	*****
Other :	0	0.0	0	*****	0	*****

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

Pesticide and Nitrate plus Nitrite Detections Related to Well Construction Sheyenne Delta Aquifer

Wells with only pesticide detections : 11 15.9 %
Wells with only nitrate detections : 12 17.4 %
Wells with pesticide & nitrate detections : 6 8.7 %
Wells with nitrate > 10 mg/L : 1 1.4 %

Total number of wells in sample population : 69

DEPTH OF WELLS		#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	19	27.5	7	36.8	4	21.1	
20 - 50 Ft. :	33	47.8	5	15.2	11	33.3	
> 50 Ft. :	16	23.2	4	25.0	2	12.5	
Unknown :	1	1.4	1	100.0	1	100.0	

DIAMETER OF WELL		#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 6 in. :	68	98.6	16	23.5	17	25.0	
6 - 18 in. :	0	0.0	0	*****	0	*****	
> 18 in. :	0	0.0	0	*****	0	*****	
Unknown :	1	1.4	1	100.0	1	100.0	

CASING MATERIAL		#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Plastic(PVC or ABS) :	65	94.2	15	23.1	16	24.6	
Concrete/Brick/Stone :	0	0.0	0	*****	0	*****	
Metallic :	3	4.3	1	33.3	1	33.3	
Other :	1	1.4	1	100.0	1	100.0	

DEPTH TO TOP OF SCREENED INTERVAL		#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	24	34.8	7	29.2	7	29.2	
20 - 50 Ft. :	33	47.8	6	18.2	9	27.3	
> 50 Ft. :	11	15.9	3	27.3	1	9.1	
Unknown :	1	1.4	1	100.0	1	100.0	

DISTANCE FROM WATER TABLE TO TOP OF SCREEN		#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 10 Ft. :	23	33.3	7	30.4	6	26.1	
10 - 30 Ft. :	23	33.3	4	17.4	9	39.1	
> 30 Ft. :	22	31.9	5	22.7	2	9.1	
Unknown :	1	1.4	1	100.0	1	100.0	

TYPE OF WELL		#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Monitoring :	44	63.8	13	29.5	8	18.2	
Private/Domestic :	19	27.5	1	5.3	7	36.8	
Livestock :	5	7.2	3	60.0	3	60.0	
Public Supply :	0	0.0	0	*****	0	*****	
Irrigation :	1	1.4	0	0.0	0	0.0	
Other :	0	0.0	0	*****	0	*****	

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

Pesticide and Nitrate plus Nitrite Detections Related to Site-Inventory Data Galesburg/Page Aquifer

Wells with only pesticide detections : 4 8.7 %
Wells with only nitrate detections : 4 8.7 %
Wells with pesticide & nitrate detections : 3 6.5 %
Wells with nitrate > 10 mg/L : 1 2.2 %

Total number of wells in sample population : 46

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
GENERAL SETTING						
Farm Yard :	9	19.6	2	22.2	2	22.2
Field :	35	76.1	6	17.1	5	14.3
Pasture :	3	6.5	0	0.0	0	0.0
C.R.P. :	0	0.0	0	*****	0	*****
Roadside :	35	76.1	6	17.1	5	14.3
Town :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEARBY FACTORS OF POSSIBLE INFLUENCE						
Near Irrigation :	9	19.6	3	33.3	2	22.2
Near Feed Lot :	5	10.9	0	0.0	1	20.0
Near Disposal Area :	0	0.0	0	*****	0	*****
Near Septic System :	11	23.9	3	27.3	2	18.2
Near Surface Water :	16	34.8	5	31.3	4	25.0
Well in Depression :	4	8.7	1	25.0	2	50.0
Near Chemical Usage :	2	4.3	1	50.0	1	50.0
Other :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR IRRIGATION						
0 - 100 ft. :	1	2.2	1	100.0	1	100.0
100 ft. - 1/8 mile :	8	17.4	2	25.0	1	12.5

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR A FEED LOT						
0 - 100 ft. :	2	4.3	0	0.0	0	0.0
100 ft. - 1/8 mile :	3	6.5	0	0.0	1	33.3

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR DISPOSAL AREA						
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SEPTIC SYSTEM						
0 - 100 ft. :	6	13.0	1	16.7	1	16.7
100 ft. - 1/8 mile :	5	10.9	2	40.0	1	20.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SURFACE WATER						
0 - 100 ft. :	1	2.2	0	0.0	0	0.0
100 ft. - 1/8 mile :	15	32.6	5	33.3	4	26.7

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
DEPRESSION AROUND WELL						
Yes :	4	8.7	1	25.0	2	50.0
No :	42	91.3	6	14.3	7	16.7
Unknown :	0	0.0	0	*****	0	*****

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR CHEMICAL USAGE, MIXING, OR STORAGE						
Pesticides :	1	2.2	0	0.0	0	0.0
Fertilizer :	1	2.2	1	100.0	1	100.0
Petroleum :	1	2.2	1	100.0	1	100.0
Other :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PESTICIDE USAGE, MIXING, OR STORAGE						
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	1	2.2	0	0.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR FERTILIZER USAGE, MIXING, OR STORAGE						
0 - 100 ft. :	1	2.2	1	100.0	1	100.0
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PETROLEUM STORAGE						
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	1	2.2	1	100.0	1	100.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
CROPS CLOSE TO WELL						
Small Grains :	26	56.5	4	15.4	3	11.5
Row Crops :	37	80.4	6	16.2	6	16.2
Hay :	6	13.0	0	0.0	0	0.0
Pasture :	1	2.2	0	0.0	1	100.0
C.R.P. :	2	4.3	1	50.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SMALL GRAIN CROPS						
0 - 100 ft. :	16	34.8	4	25.0	2	12.5
100 ft. - 1/8 mile :	10	21.7	0	0.0	1	10.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR ROW CROPS						
0 - 100 ft. :	29	63.0	5	17.2	5	17.2
100 ft. - 1/8 mile :	8	17.4	1	12.5	1	12.5

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR HAY CROPS						
0 - 100 ft. :	4	8.7	0	0.0	0	0.0
100 ft. - 1/8 mile :	2	4.3	0	0.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PASTURE						
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	1	2.2	0	0.0	1	100.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR C.R.P.						
0 - 100 ft. :	1	2.2	1	100.0	0	0.0
100 ft. - 1/8 mile :	1	2.2	0	0.0	0	0.0

Pesticide and Nitrate plus Nitrite Detections Related to Site-Inventory Data Hankinson Aquifer

Wells with only pesticide detections : 5 20.0 %
Wells with only nitrate detections : 3 12.0 %
Wells with pesticide & nitrate detections : 3 12.0 %
Wells with nitrate > 10 mg/L : 0 0.0 %

Total number of wells in sample population : 25

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
GENERAL SETTING						
Farm Yard :	15	60.0	3	20.0	3	20.0
Field :	9	36.0	3	33.3	4	44.4
Pasture :	5	20.0	3	60.0	1	20.0
C.R.P. :	0	0.0	0	*****	0	*****
Roadside :	11	44.0	4	36.4	4	36.4
Town :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEARBY FACTORS OF POSSIBLE INFLUENCE						
Near Irrigation :	1	4.0	0	0.0	0	0.0
Near Feed Lot :	1	4.0	1	100.0	1	100.0
Near Disposal Area :	1	4.0	1	100.0	1	100.0
Near Septic System :	15	60.0	5	33.3	3	20.0
Near Surface Water :	14	56.0	6	42.9	4	28.6
Well in Depression :	1	4.0	1	100.0	1	100.0
Near Chemical Usage :	12	48.0	5	41.7	3	25.0
Other :	1	4.0	0	0.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR IRRIGATION						
0 - 100 ft. :	1	4.0	0	0.0	0	0.0
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR A FEED LOT						
0 - 100 ft. :	1	4.0	1	100.0	1	100.0
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR DISPOSAL AREA						
0 - 100 ft. :	1	4.0	1	100.0	1	100.0
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SEPTIC SYSTEM						
0 - 100 ft. :	6	24.0	1	16.7	1	16.7
100 ft. - 1/8 mile :	9	36.0	4	44.4	2	22.2

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SURFACE WATER						
0 - 100 ft. :	2	8.0	2	100.0	0	0.0
100 ft. - 1/8 mile :	12	48.0	6	50.0	4	33.3

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
DEPRESSION AROUND WELL						
Yes :	1	4.0	1	100.0	0	0.0
No :	24	96.0	7	29.2	6	25.0
Unknown :	0	0.0	0	*****	0	*****

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR CHEMICAL USAGE, MIXING, OR STORAGE						
Pesticides :	4	16.0	2	50.0	1	25.0
Fertilizer :	0	0.0	0	*****	0	*****
Petroleum :	8	32.0	3	37.5	2	25.0
Other :	2	8.0	0	0.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PESTICIDE USAGE, MIXING, OR STORAGE						
0 - 100 ft. :	2	8.0	0	0.0	1	50.0
100 ft. - 1/8 mile :	2	8.0	2	100.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR FERTILIZER USAGE, MIXING, OR STORAGE						
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PETROLEUM STORAGE						
0 - 100 ft. :	3	12.0	3	100.0	1	33.3
100 ft. - 1/8 mile :	5	20.0	1	20.0	1	20.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
CROPS CLOSE TO WELL						
Small Grains :	3	12.0	0	0.0	1	33.3
Row Crops :	16	64.0	5	31.3	4	25.0
Hay :	1	4.0	0	0.0	0	0.0
Pasture :	7	28.0	4	57.1	1	14.3
C.R.P. :	1	4.0	0	0.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SMALL GRAIN CROPS						
0 - 100 ft. :	3	12.0	0	0.0	1	33.3
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR ROW CROPS						
0 - 100 ft. :	5	20.0	3	60.0	3	60.0
100 ft. - 1/8 mile :	11	44.0	2	18.2	1	9.1

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR HAY CROPS						
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	1	4.0	0	0.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PASTURE						
0 - 100 ft. :	6	24.0	3	50.0	0	0.0
100 ft. - 1/8 mile :	1	4.0	1	100.0	1	100.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR C.R.P.						
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	1	4.0	0	0.0	0	0.0

Pesticide and Nitrate plus Nitrite Detections Related to Site-Inventory Data Kidder/Marstonmoor Plain Aquifer

Wells with only pesticide detections : 4 4.5 %
Wells with only nitrate detections : 16 18.0 %
Wells with pesticide & nitrate detections : 1 1.1 %
Wells with nitrate > 10 mg/L : 3 3.4 %

Total number of wells in sample population : 89

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
GENERAL SETTING						
Farm Yard :	14	15.7	2	14.3	2	14.3
Field :	41	46.1	2	4.9	11	26.8
Pasture :	24	27.0	1	4.2	4	16.7
C.R.P. :	13	14.6	0	0.0	3	23.1
Roadside :	60	67.4	2	3.3	12	20.0
Town :	3	3.4	1	33.3	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEARBY FACTORS OF POSSIBLE INFLUENCE						
Near Irrigation :	32	36.0	0	0.0	11	34.4
Near Feed Lot :	15	16.9	2	13.3	1	6.7
Near Disposal Area :	1	1.1	0	0.0	0	0.0
Near Septic System :	20	22.5	4	20.0	2	10.0
Near Surface Water :	37	41.2	3	8.1	4	10.8
Well in Depression :	4	4.5	0	0.0	0	0.0
Near Chemical Usage :	10	11.2	1	10.0	2	20.0
Other :	1	1.1	0	0.0	1	100.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR IRRIGATION						
0 - 100 ft. :	3	3.4	0	0.0	1	33.3
100 ft. - 1/8 mile :	29	32.6	0	0.0	10	34.5

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR A FEED LOT						
0 - 100 ft. :	5	5.6	1	20.0	0	0.0
100 ft. - 1/8 mile :	10	11.2	1	10.0	1	10.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR DISPOSAL AREA						
0 - 100 ft. :	0	0.0	0	****	0	****
100 ft. - 1/8 mile :	1	1.1	0	0.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SEPTIC SYSTEM						
0 - 100 ft. :	8	9.0	2	25.0	0	0.0
100 ft. - 1/8 mile :	12	13.5	2	16.7	2	16.7

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SURFACE WATER						
0 - 100 ft. :	5	5.6	0	0.0	0	0.0
100 ft. - 1/8 mile :	32	36.0	3	9.4	4	12.5

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
DEPRESSION AROUND WELL						
Yes :	4	4.5	0	0.0	0	0.0
No :	85	95.5	5	5.9	17	20.0
Unknown :	0	0.0	0	****	0	****

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR CHEMICAL USAGE, MIXING, OR STORAGE						
Pesticides :	5	5.6	1	20.0	2	40.0
Fertilizer :	0	0.0	0	****	0	****
Petroleum :	6	6.7	0	0.0	1	16.7
Other :	0	0.0	0	****	0	****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PESTICIDE USAGE, MIXING, OR STORAGE						
0 - 100 ft. :	3	3.4	0	0.0	1	33.3
100 ft. - 1/8 mile :	2	2.2	1	25.0	1	50.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR FERTILIZER USAGE, MIXING, OR STORAGE						
0 - 100 ft. :	0	0.0	0	****	0	****
100 ft. - 1/8 mile :	0	0.0	0	****	0	****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PETROLEUM STORAGE						
0 - 100 ft. :	1	1.1	0	0.0	0	0.0
100 ft. - 1/8 mile :	5	5.6	0	0.0	1	20.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
CROPS CLOSE TO WELL						
Small Grains :	27	30.3	1	3.7	4	14.8
Row Crops :	38	42.7	1	2.6	10	26.3
Hay :	54	60.7	3	5.6	15	27.8
Pasture :	41	46.1	1	2.4	6	14.6
C.R.P. :	24	27.0	1	4.2	4	16.7

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SMALL GRAIN CROPS						
0 - 100 ft. :	10	11.2	0	0.0	0	0.0
100 ft. - 1/8 mile :	17	19.1	1	5.9	4	23.5

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR ROW CROPS						
0 - 100 ft. :	10	11.2	0	0.0	1	10.0
100 ft. - 1/8 mile :	28	31.5	1	3.6	9	32.1

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR HAY CROPS						
0 - 100 ft. :	33	37.1	1	3.0	10	30.0
100 ft. - 1/8 mile :	21	23.6	1	4.8	5	23.8

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PASTURE						
0 - 100 ft. :	29	32.6	1	3.4	5	17.2
100 ft. - 1/8 mile :	12	13.5	0	0.0	1	8.3

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR C.R.P.						
0 - 100 ft. :	16	17.8	1	6.3	3	18.8
100 ft. - 1/8 mile :	8	9.0	0	0.0	1	12.5

Pesticide and Nitrate plus Nitrite Detections Related to Site-Inventory Data Milnor Channel Aquifer

Wells with only pesticide detections : 5 8.2 %
Wells with only nitrate detections : 10 16.4 %
Wells with pesticide & nitrate detections : 1 1.6 %
Wells with nitrate > 10 mg/L : 0 0.0 %

Total number of wells in sample population : 61

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
GENERAL SETTING						
Farm Yard :	29	47.5	3	10.3	6	20.7
Field :	25	41.0	3	12.0	5	20.0
Pasture :	6	9.8	0	0.0	1	16.7
C.R.P. :	1	1.6	0	0.0	0	0.0
Roadside :	26	42.6	1	3.8	6	23.1
Town :	2	3.3	1	50.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEARBY FACTORS OF POSSIBLE INFLUENCE						
Near Irrigation :	10	16.4	0	0.0	3	30.0
Near Feed Lot :	17	27.9	1	5.9	3	17.6
Near Disposal Area :	0	0.0	0	*****	0	*****
Near Septic System :	34	55.7	3	8.8	6	17.6
Near Surface Water :	35	57.4	5	14.3	6	17.1
Well in Depression :	2	3.3	0	0.0	0	0.0
Near Chemical Usage :	12	19.7	2	16.7	1	8.3
Other :	1	1.6	1	100.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR IRRIGATION						
0 - 100 ft. :	1	1.6	0	0.0	0	0.0
100 ft. - 1/8 mile :	9	14.8	0	0.0	3	33.3

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR A FEED LOT						
0 - 100 ft. :	4	6.6	0	0.0	0	0.0
100 ft. - 1/8 mile :	13	21.3	1	7.7	3	23.1

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR DISPOSAL AREA						
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SEPTIC SYSTEM						
0 - 100 ft. :	24	39.3	2	8.3	5	20.8
100 ft. - 1/8 mile :	10	16.4	1	10.0	1	10.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SURFACE WATER						
0 - 100 ft. :	12	19.7	2	16.7	3	25.0
100 ft. - 1/8 mile :	23	37.7	2	8.7	3	13.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
DEPRESSION AROUND WELL						
Yes :	2	3.3	0	0.0	0	0.0
No :	57	93.4	5	8.8	11	19.3
Unknown :	2	3.3	1	50.0	0	0.0

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR CHEMICAL USAGE, MIXING, OR STORAGE						
Pesticides :	4	6.6	1	25.0	0	0.0
Fertilizer :	1	1.6	1	100.0	0	0.0
Petroleum :	9	14.8	1	11.1	1	11.1
Other :	1	1.6	0	0.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PESTICIDE USAGE, MIXING, OR STORAGE						
0 - 100 ft. :	2	3.3	1	50.0	0	0.0
100 ft. - 1/8 mile :	2	3.3	0	0.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR FERTILIZER USAGE, MIXING, OR STORAGE						
0 - 100 ft. :	1	1.6	1	100.0	0	0.0
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PETROLEUM STORAGE						
0 - 100 ft. :	7	11.5	0	0.0	1	14.3
100 ft. - 1/8 mile :	2	3.3	1	50.0	0	0.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
CROPS CLOSE TO WELL						
Small Grains :	14	23.0	2	14.3	2	14.3
Row Crops :	42	68.9	5	11.9	9	21.4
Hay :	11	18.0	0	0.0	3	27.3
Pasture :	21	34.4	0	0.0	2	9.5
C.R.P. :	2	3.3	0	0.0	1	50.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR SMALL GRAIN CROPS						
0 - 100 ft. :	6	9.8	2	33.3	0	0.0
100 ft. - 1/8 mile :	8	13.1	0	0.0	2	25.0

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR ROW CROPS						
0 - 100 ft. :	16	26.2	2	12.5	5	31.3
100 ft. - 1/8 mile :	26	42.6	3	11.5	4	15.4

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR HAY CROPS						
0 - 100 ft. :	4	6.6	0	0.0	0	0.0
100 ft. - 1/8 mile :	7	11.5	0	0.0	3	42.9

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR PASTURE						
0 - 100 ft. :	10	16.4	0	0.0	1	10.0
100 ft. - 1/8 mile :	11	18.0	0	0.0	1	9.1

	#	%	PEST. DET.	PEST. DET.	NO3 DET.	NO3 DET.
NEAR C.R.P.						
0 - 100 ft. :	1	1.6	0	0.0	0	0.0
100 ft. - 1/8 mile :	1	1.6	0	0.0	1	100.0

Pesticide and Nitrate plus Nitrite Detections Related to Site-Inventory Data Sheyenne Delta Aquifer

Wells with only pesticide detections : 11 15.9 %
Wells with only nitrate detections : 12 17.4 %
Wells with pesticide & nitrate detections : 6 8.7 %
Wells with nitrate > 10 mg/L : 1 1.4 %

Total number of wells in sample population : 69

		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
GENERAL SETTING		#	%						
Farm Yard :	24	34.8	3	12.5	10	41.7			
Field :	34	49.3	8	23.5	4	11.8			
Pasture :	24	34.8	10	41.7	8	33.3			
C.R.P. :	0	0.0	0	*****	0	*****			
Roadside :	36	52.2	11	30.6	8	22.2			
Town :	1	1.4	1	100.0	0	0.0			
NEARBY FACTORS OF POSSIBLE INFLUENCE		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
Near Irrigation :	13	18.8	2	15.4	3	23.1			
Near Feed Lot :	18	26.1	3	16.7	9	50.0			
Near Disposal Area :	1	1.4	0	0.0	0	0.0			
Near Septic System :	33	47.8	5	15.2	12	36.4			
Near Surface Water :	28	40.6	10	35.7	10	35.7			
Well in Depression :	1	1.4	0	0.0	0	0.0			
Near Chemical Usage :	9	13.0	3	33.3	5	55.6			
Other :	3	4.3	1	33.3	1	33.3			
NEAR IRRIGATION		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****			
100 ft. - 1/8 mile :	13	18.8	2	15.4	3	23.1			
NEAR A FEED LOT		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	6	8.7	2	33.3	3	50.0			
100 ft. - 1/8 mile :	12	17.4	1	8.3	6	50.0			
NEAR DISPOSAL AREA		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****			
100 ft. - 1/8 mile :	1	1.4	0	0.0	0	0.0			
NEAR SEPTIC SYSTEM		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	15	21.7	3	20.0	5	33.3			
100 ft. - 1/8 mile :	18	26.1	2	11.1	7	38.9			
NEAR SURFACE WATER		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	9	13.0	5	55.6	3	33.3			
100 ft. - 1/8 mile :	19	27.5	5	26.3	7	36.8			
DEPRESSION AROUND WELL		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
Yes :	1	1.4	0	0.0	0	0.0			
No :	68	98.6	17	25.0	18	26.5			
Unknown :	0	0.0	0	*****	0	*****			

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

NEAR CHEMICAL USAGE, MIXING, OR STORAGE		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
Pesticides :	4	5.8	1	25.0	2	50.0			
Fertilizer :	4	5.8	1	25.0	1	25.0			
Petroleum :	9	13.0	3	33.3	4	44.4			
Other :	0	0.0	0	*****	0	*****			
NEAR PESTICIDE USAGE, MIXING, OR STORAGE		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****			
100 ft. - 1/8 mile :	4	5.8	1	25.0	2	50.0			
NEAR FERTILIZER USAGE, MIXING, OR STORAGE		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****			
100 ft. - 1/8 mile :	4	5.8	1	25.0	1	25.0			
NEAR PETROLEUM STORAGE		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	4	5.8	1	25.0	1	25.0			
100 ft. - 1/8 mile :	5	7.2	2	40.0	3	60.0			
CROPS CLOSE TO WELL		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
Small Grains :	6	8.7	2	33.3	3	50.0			
Row Crops :	34	49.3	8	23.5	9	26.5			
Hay :	11	15.9	4	36.4	5	45.5			
Pasture :	27	39.1	8	29.6	8	29.6			
C.R.P. :	4	5.8	0	0.0	0	0.0			
NEAR SMALL GRAIN CROPS		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	1	1.4	0	0.0	1	100.0			
100 ft. - 1/8 mile :	5	7.2	2	40.0	2	40.0			
NEAR ROW CROPS		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	12	17.4	2	16.7	1	8.3			
100 ft. - 1/8 mile :	22	31.9	6	27.3	8	36.4			
NEAR HAY CROPS		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	7	10.1	3	42.9	3	42.9			
100 ft. - 1/8 mile :	4	5.8	1	25.0	2	50.0			
NEAR PASTURE		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	18	26.1	7	38.9	6	33.3			
100 ft. - 1/8 mile :	9	13.0	1	11.1	2	22.2			
NEAR C.R.P.		#	%	PEST. DET.	PEST. DET.	#	%	NO3 DET.	NO3 DET.
0 - 100 ft. :	3	4.3	0	0.0	0	0.0			
100 ft. - 1/8 mile :	1	1.4	0	0.0	0	0.0			

APPENDIX E

Health Advisories

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HEALTH ADVISORIES

The Health Advisory Program, sponsored by EPA's Office of Drinking Water, provides information about the health effects, analytical methodology and treatment technology that would be useful in dealing with contamination of water resources. Health advisories describe nonregulatory concentrations of drinking water contaminants called health advisory levels (HALs), at which adverse health effects would not be anticipated to occur over specific exposure durations. HALs contain a margin of safety to protect sensitive members of the population. Health advisories serve as informal technical guidelines to assist in protecting public health. They are not to be construed as legally enforceable federal standards. The HALs are subject to change as new information becomes available.

The Safe Drinking Water Act has specified maximum contaminant levels (MCLs) for a variety of organic and inorganic constituents. MCLs are enforceable for public water systems, but are not enforceable for private or individual water systems. HALs and MCLs do not address other beneficial uses of water such as irrigation or discharge to surface water.

The development of HALs and MCLs is based on essentially the same criteria. HALs are developed for one-day, 10-day, longer-term (approximately seven years or 10 percent of an individual's lifetime), and lifetime exposures. The Lifetime Exposure HAL includes a factor to account for exposure to the contaminant from sources other than drinking water. An MCL is essentially the same as a Lifetime Exposure HAL.

Seven pesticides or pesticide degradation products, as well as nitrate plus nitrite, were detected in samples collected for this study. A summary of health advisory information for these contaminants follows. All information included is from EPA, Office of Drinking Water, health advisory bulletins; the *Farm Chemicals Handbook '97*; the *Handbook of Environmental Data on Organic Chemicals*; the *Merck Index*; the *International Union of Pure and Applied Chemistry (IUPAC)*; and *Pesticide Use and Pest Management Practices for Major Crops in North Dakota, 1996*, unless stated otherwise.

Atrazine

Common names: Common trade names for atrazine are Aatrex, Atronex, Crisatrina, Crisazine, Farmco Atrazine, Griffex, Vectal SC, Gesaprim and Primatol.

Chemical formula: The empirical chemical formula for atrazine is $C_8H_{14}ClN_5$. Its composition is 2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine (IUPAC).

Physical properties: At room temperature, pure atrazine is a white, odorless, crystalline solid with a solubility in water of 70 mg/l. It has a melting point in the range of 175 degrees to 177 degrees C and vapor pressure of 3.0×10^{-7} mmHg at 20 degrees C. Retail formulations of atrazine include liquid concentrate, water-dispersible granules and wettable powders.

Uses and occurrence: Atrazine is a widely used selective herbicide for control of broadleaf and grassy weeds in corn, sorghum, rangeland and turf grass. During the past 30 years, atrazine has been the most heavily used herbicide in the United States. In 1996, atrazine was applied to approximately 91,700 acres in North Dakota, either alone or in formulation with another herbicide (Zollinger et al., 1998).

Environmental fate: Microbial activity accounts for decomposition of a significant portion of atrazine in the soil. A range of soil microorganisms use atrazine as a source of energy and nitrogen. Atrazine will persist longer under dry, cold conditions or conditions not conducive to maximum biological activity. Photodecomposition and volatilization of atrazine from soil are very slow processes and are of little significance in dissipation of the chemical under field conditions.

Health effects: Studies on rats show that atrazine is readily absorbed by the gastrointestinal tract when administered orally at low dosage levels. Approximately 85 percent of atrazine was excreted unchanged. The acute oral LD_{50} value in rats is 3,000 mg/kg. Studies of the dermal effects of atrazine have shown that it produces erythema in rats during dermal irritation tests but no systemic effects. A case of severe contact dermatitis was reported in a 40-year-old farm worker who was severely exposed to atrazine. Symptoms included red, swollen and blistered hands with hemorrhagic blisters between the fingers. No other symptoms were reported. Studies

that evaluated the carcinogenic potential of atrazine showed an increased incidence in mammary tumors in rats. Atrazine has been classified in Group C: possible human carcinogen. This category is used for substances with limited evidence of carcinogenicity from animal studies and inadequate or no data in humans.

Health advisory level: The MCL for atrazine is 0.003 mg/l ($3\mu\text{g/l}$ or 3 ppb).

Treatment technologies: Studies show that activated carbon adsorption, ion exchange, reverse osmosis, ozone oxidation and ultraviolet irradiation are the most promising treatment technologies for removing atrazine from water sources.

Bentazon

Common names: Common trade names for bentazon are Basagran, Bendioxide and Bentazone.

Chemical formula: The empirical chemical formula for bentazon is $\text{C}_{10}\text{H}_{12}\text{N}_2\text{O}_3\text{S}$. Its composition is 3-(1methylethyl)-1H-2,1,3-benzothiadiazin-4(3H)-one,2,2-dioxide (IUPAC).

Physical properties: At room temperature, bentazon is a crystalline powder that has no odor or color. It has a solubility of 500 mg/l and a melting point in the range of 137 degrees to 139 degrees C. The retail formulation is a soluble concentrate.

Uses and occurrence: Bentazon is a selective herbicide that controls a number of broadleaf and sedge weeds. It is used primarily in most gramineous and many large-seeded leguminous crops. In 1996, bentazon was applied to approximately 667,900 acres in North Dakota (Zollinger et al., 1998).

Environmental fate: Bentazon is a very mobile chemical in soil and water. It is hydrolyzed poorly and undergoes photodecomposition very slowly, but is rapidly degraded by bacteria and fungi. The speed of degradation is decreased by decreasing temperature. The half-life of bentazon under these conditions is less than one month.

Health effects: Small doses of bentazon are almost completely absorbed when ingested by mammals. It is not metabolized significantly in the body, however, small traces of two unidentified metabolites have been detected. Approximately 92 percent of the ingested bentazon passes through the body and is excreted. No information about the health effects of this chemical in the human body was available. The LD₅₀ for various species of animals, however, ranged from approximately 500 to 1100 mg/kg. No valid data was available to make a determination of the carcinogenic potential of bentazon. Because of this, bentazon has been included in Group D: not classifiable. This group is generally used for substances with inadequate or no human and animal evidence of carcinogenicity.

Health advisory level: The lifetime HAL for bentazon has been set at 0.02 mg/l (20 µg/l or 20 ppb).

Treatment technologies: No information was available about treatment technologies used to effectively remove bentazon from contaminated water.

Bromoxynil

Common names: Common trade names for bromoxynil are Brominal, Bromotril, Buctril, Bronate, Merit, Pardner, Saber and Torch.

Chemical formula: The empirical chemical formula for bromoxynil is C₇H₃Br₂NO. The composition of bromoxynil is 3,5-dibromo-4-hydroxybenzonitrile.

Physical characteristics: At room temperature pure bromoxynil is an odorless, white or colorless crystalline solid or light buff to creamy powder. It has a melting point of 194 degrees to 195 degrees C and a low solubility in water of 130 mg/l. Retail formulations of bromoxynil include emulsifiable concentrates and suspended concentrates.

Uses and occurrence: Bromoxynil is a restricted-use pesticide (RUP) and is not registered for homeowner use. Bromoxynil is a selective contact herbicide with some activity for post-emergence control of annual broadleaf weeds. It is used on corn, wheat, barley, flax, oats, triticale, onions, alfalfa and lawns. In 1996, bromoxynil was used on approximately 1,831,500

agricultural acres in North Dakota (Zollinger et al., 1998).

Environmental fate: Bromoxynil has a low persistence in soil, with persistence dependent upon soil type. The half-life of bromoxynil in sandy soil is approximately 10 days. It degrades somewhat more slowly in clay, with a half-life of about two weeks (EXTOXNET, 1996). It is expected to adsorb moderately to soil at low pHs but not at neutral or higher pHs (Chemical Abstract Services, CAS # 1689-84-5). Bromoxynil is broken down by soil bacteria, but evidence suggests that it may inhibit the action of other bacteria that promote nitrification (EXTOXNET, 1996). Bromoxynil is subject to photolysis on the soil surface and in surface layers of water. It does not appear to bioconcentrate in aquatic organisms.

Health effects: The acute oral LD₅₀ of technical bromoxynil is 190 mg/kg in rats, while the oral LD₅₀ of the bromoxynil product, Buctril, is 779 mg/kg in rats. Human exposure to bromoxynil is primarily occupational. In one case of chronic exposure, symptoms observed were weight loss, fever, vomiting, headache and urinary problems (EXTOXNET, 1996).

Health advisory level: There is no MCL or HAL for bromoxynil.

Treatment technologies: No information was found about treatment technologies for removing bromoxynil from drinking water.

Carbaryl

Common names: Carbaryl is most commonly known by the trade name Sevin. Other trade names are Adios, Bugmaster, Carbamec, Barbamine, Crunch, Denapon, Dicarbam, Hexavin, Karbaspray, Nac, Rayvon, Septene, Tercyl, Thinsec and Vioxan.

Chemical formula: The empirical chemical formula for carbaryl is C₁₂H₁₁NO₂. Its composition is 1-naphthyl methylcarbamate.

Physical properties: At room temperature, carbaryl varies from colorless to white or gray odorless crystals, depending upon the purity of the compound. Carbaryl is stable to heat, light and acids, but hydrolyzes rapidly in alkaline solutions. It has a solubility of 40 mg/l in water and

a melting point of 145 degrees C. Retail formulations are available as bait, dusts, wettable powders, granules, dispersions and suspensions (EXTOXNET, 1996).

Uses and occurrence: Carbaryl is a broad-spectrum insecticide used on many crops including citrus, fruit, cotton, vegetables, forage crops, forests, lawns, nuts, ornamentals, rangeland, turf and shade trees, as well as on poultry, livestock and pets. In 1996, carbaryl was applied to approximately 25,800 acres in North Dakota (Zollinger et al., 1998).

Environmental fate: Carbaryl has a low persistence in soil and degrades mainly from sunlight and bacterial action. It binds to organic matter and can be transported in soil runoff. Carbaryl has a half-life of seven to 14 days in sandy loam soil and 14 to 28 days in clay loam soil. Degradation of carbaryl in surface water occurs through bacterial action and hydrolysis. Evaporation is very slow. The half-life of carbaryl in surface water is about 10 days at neutral pH; however, the half-life varies greatly depending upon surface acidity. Hydrolysis of carbaryl occurs inside plants, with a short residual life of less than two weeks. The breakdown of carbaryl is strongly dependent upon acidity and temperature. The metabolic products of carbaryl degradation have a lower toxicity to humans than carbaryl itself (EXTOXNET).

Health effects: Carbaryl is moderately to very toxic. It can produce adverse effects in humans by skin contact, inhalation or ingestion. Direct contact of the skin or eyes with moderate levels of carbaryl can cause burns. Ingesting or inhaling very large amounts can be toxic to the nervous and respiratory systems resulting in nausea, stomach cramps, diarrhea, excessive salivation, sweating, blurred vision, incoordination and convulsions. There is only one documented human fatality from carbaryl, and that was from intentionally ingesting the insecticide (EXTOXNET). Human exposure to carbaryl is expected to be mainly from ingestion of contaminated food, and occupational exposure in farm workers is expected (Chemical Abstract Services). Technical-grade carbaryl has not been demonstrated to cause tumors in long-term and lifetime laboratory animal studies; thus the indications are that carbaryl is unlikely to be carcinogenic to humans (EXTOXNET). Therefore, carbaryl is included Group D: not classifiable. This category is used for substances with inadequate or no human and animal evidence of carcinogenicity.

Health advisory level: The lifetime HAL for carbaryl has been set at 0.70 mg/l (700 µg/l or 700 ppb).

Treatment technologies: Treatment technologies capable of removing carbaryl from drinking water are granular-activated carbon (GAC) adsorption, ozonation and conventional water treatment by alum coagulation and filtration.

Cyanazine

Common names: Common trade names for cyanazine are Cyanazine, Bladex, Fortrol and Payze.

Chemical formula: The empirical chemical formula for cyanazine is $C_9H_{13}ClN_6$. The composition of cyanazine is 2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2-methylpropanenitrile (IUPAC).

Physical characteristics: Cyanazine is an odorless, white or colorless crystalline solid that is incompatible with metals. Cyanazine has a water solubility of 171 mg/l at room temperature and a melting point of 167.5 degrees to 169 degrees C. Retail formulations include dry flowable, liquids, granules and wettable powders.

Uses and occurrence: Cyanazine is a triazine, a group of chemically similar herbicides that also includes atrazine, propazine and simazine. Cyanazine is a selective herbicide applied pre- and post-emergent for the control of broadleaf weeds and annual grasses. It is used mostly on corn, with some use on cotton, grain sorghum and wheat fallow. In 1996, cyanazine was applied to approximately 49,000 agricultural acres in North Dakota (Zollinger et al., 1998). In the United States, registration of cyanazine was canceled as of Jan. 1, 2000, although the sale and distribution of existing stock may continue through Sept. 30, 2002, with all use prohibited after Dec. 31, 2002.

Environmental fate: Cyanazine has a low to moderate persistence in soil. In laboratory studies, cyanazine had a half-life of two to 14 weeks. Cyanazine does not hydrolyze and is relatively resistant to photolysis; decomposition occurs mostly from microbial action. Mobility varies from low to readily mobile and the degradation products are all mobile to very mobile. In laboratory studies, cyanazine residues leached readily. In terrestrial field dissipation studies, recovery in certain soils was 72 percent to 100 percent, even up to 52 weeks.

Health effects: Cyanazine is rapidly absorbed from the gastrointestinal tract when administered orally at low dosage levels. Symptoms include labored breathing, blood in the saliva, inactivity and depression. Among observed effects were decreased body weight gain, increased liver weight, birth defects, central nervous system depression and developmental toxicity. Acute oral LD₅₀ levels in rats range from 182 to 332 mg/kg. No information was found in the available literature about the health effects of cyanazine in humans. Cyanazine has a chemical structure analogous to atrazine, propazine and simazine. Based on structure-activity relationship, cyanazine may reflect a similar pattern of toxicity. These three analogs were found to significantly increase the incidence of mammary tumors in rats. Cyanazine is classified in Group C for carcinogenicity: possible human carcinogen. This category is used for substances for which there is limited evidence of carcinogenicity in animal studies and inadequate or no evidence in humans.

Health advisory level: There is no MCL for cyanazine. The lifetime HAL has been set at 0.001 mg/l (1 µg/l or 1 ppb).

Treatment technologies: Available data indicate that granular-activated carbon adsorption will remove cyanazine from drinking water.

2,4-Dichlorophenoxyacetic Acid (2,4-D)

Common names: Trade names for 2,4-D are 2,4-D; Amoxone; Aqua-Kleen; Chloroxone; and Weed-B-Gone.

Chemical formula: The empirical chemical formula for 2,4-D is C₈H₆O₃Cl₂. The composition for 2,4-D is 2,4-dichlorophenoxyacetic acid (IUPAC).

Physical properties: 2,4-D is a white crystalline powder. The melting point of 2,4-D is 140.5 degrees C. It is only slightly soluble in water, 900 mg/l, and in petroleum distillate; however, it is soluble in organic solvents and alcohols. The acid customarily is not used by itself, but usually as an amine, salt or ester. The esters are soluble in oils, and the amine salts are soluble in water. Retail formulations include the emulsion form (esters), aqueous solutions (salts) and amines, of which the amine in largest production is the dimethylamine salt. As with amines which form

salts with the 2,4-D acid, esters are made with a wide variety of alcohols.

Uses and occurrence: 2,4-D is a selective, systemic herbicide widely used in North Dakota to control broadleaf weeds in wheat, barley, oats, flax, corn, sunflowers, soybeans, dry beans, potatoes, alfalfa and other hay, pasture, summer fallow and CRP. 2,4-D is the most widely used herbicide in North Dakota. In 1996, it was applied, alone, to 7,907,100 acres, or 19.1 percent of the agricultural acres in the state. In conjunction with other chemicals, it was applied to an additional 1,425,000 acres (Zollinger et al., 1998).

Environmental fate: 2,4-D is degraded in the environment and is not considered to be a persistent compound. It is metabolized by plants, readily degraded by soil bacteria and undergoes hydrolysis under environmental conditions. The half-life of 2,4-D is reported to be from one to six weeks in soil. Once in the soil, 2,4-D and some of its salts and esters have been demonstrated to migrate. 2,4-D does not tend to accumulate in soils and reportedly does not bioaccumulate in plants and animals. Many broadleaf crops are extremely sensitive to 2,4-D.

Health effects: 2,4-D is absorbed almost completely after ingestion. 2,4-D acid is distributed into blood, liver, kidney, heart, lungs and spleen, with lower levels occurring in muscle and brain. The data indicate that 2,4-D does not undergo biotransformation to any great extent. A male agricultural student who ingested at least six grams of a commercial herbicide preparation of the dimethyl amine salt of 2,4-D died after vomiting and convulsions. Pathological examination showed degenerative ganglion cell changes in the brain. Occupational exposure to 2,4-D has resulted in reduced nerve conduction velocities. Case-controlled epidemiological studies of populations in Scandinavian countries exposed to the phenoxy herbicides indicate excess risk of the development of soft-tissue sarcomas and malignant lymphomas. Acute oral LD₅₀ values of approximately 350 to 1000 mg/kg of 2,4-D acid have been reported for small mammals. An LD₅₀ of 100 mg/kg in dogs was reported. 2,4-D is classified in Group D: not classifiable. This category is for agents with inadequate or no human and animal evidence of carcinogenicity.

Health advisory level: The MCL and the lifetime HAL for 2,4-D have been set at 0.07 mg/l (70 µg/l or 70 ppb).

Treatment technologies: Treatment technologies capable of removing 2,4-D from drinking water

are adsorption by granular or powdered carbon and reverse osmosis.

DDT

Common names: Common trade names for DDT are Anofex, Chlorophenothane, Dedelo, Pentachlorin, Rukseam, R50, Zerdane, Helio tox and Genitox.

Chemical formula: The empirical chemical formula for DDT is $C_{14}H_9Cl_5$. Its composition is 1,1,1-trichloro-2,2-bis-(4'-chlorophenyl)ethane.

Physical properties: Chemically pure DDT consists of white or colorless needles. Technical grade DDT is a waxy solid and is actually a mixture of three isomers of DDT, principally the p,p'-DDT isomer (EXTOXNET). It is extremely nonvolatile and almost insoluble in water. It is soluble in apolar organic solvents and has limited solubility in aliphatic oils. DDT has a melting point of 108.5 degrees C and a boiling point of 260 degrees C. It possesses a fruit-like odor, or may be odorless or have a slight aromatic odor. It is unstable in the presence of alkalies, and some clays may cause slight decomposition. Retail formulations of DDT included aerosols, dusts, emulsifiable concentrates, granules, solutions and wettable powders. Due to a caking tendency either before or after grinding, it was often mixed with an equal amount of pyrophyllite or talc before grinding.

Uses and occurrence: DDT is an organochlorine non-systemic stomach and contact insecticide. Once widely used in the United States, all uses of DDT, except emergency public health uses and a few other uses permitted on a case-by-case basis, were canceled in the United States as of Jan. 1, 1973. These uses include the following: (1) by the U.S. Public Health Services and other health service officials for control of vector diseases; (2) by the U.S. Department of Agriculture or military for health quarantine; (3) in drugs, for controlling body lice; and (4) in the formulation for controlling body lice, DDT can be used for a few specialized emergency purposes, for example, to combat the tussock moth. However, DDT may still be in use elsewhere as a pesticide against mosquitos for the prevention of malaria, yellow fever and control of tsetse flies. Former uses in the United States were for the control of malaria, typhus and other insect-transmitted diseases, and for controlling mosquito larvae and adults, flies, body lice, bedbugs and flea pests of livestock. It also was used as an insecticide on farm crops including

vegetables, field crops and cotton; forest and shade trees; and stored products (Chemical Abstract Services, CAS # 50293). According to the National Institute of Environmental Health Sciences (NIEHS), before 1945, all of the DDT produced in the United States was used by the military. When it became available commercially in 1945, the results were so spectacular that U.S. consumption reached 57 million pounds in 1950, then peaked in 1959 at 78 million pounds.

Environmental fate: DDT is very persistent in the environment. DDT adsorbs very strongly to soil and is subject to evaporation and photodegradation at the surface of soils; however, the presence of DDT in samples far away from places where DDT is used suggests that photodegradation may be slow. Reports of half-lives for biodegradation in soil range from two years to more than 15 years. It will not leach appreciably to groundwater, and if released to water, it will adsorb very strongly to sediments. It will not hydrolyze and will not significantly biodegrade in most waters. If released to the air it will be subject to direct photodegradation. Under simulated atmospheric conditions, DDT decomposes to form carbon dioxide and hydrochloric acid. DDT has been demonstrated to significantly bioaccumulate in the environment, especially in fish.

Health effects: Potential human exposure is presumed to be widespread: DDT has been detected in air, rain, soil, water, animal and plant tissues, food and the work environment. Despite the cancellation of DDT usage almost 30 years ago, human exposure to DDT potentially is great because of its extensive former use and the persistence of the compound and its metabolites in the environment.

With the release of Rachel Carson's book *Silent Spring* in 1962, the emotional public reaction launched the modern environmental movement. The book's claims that pesticides, especially DDT, were poisoning wildlife and the environment and endangering human health made DDT the prime target of the growing anti-chemical and anti-pesticide movement (American Council on Science and Health, 1998). Since then, numerous harmful health effects have been attributed to DDT, some based on animal laboratory studies and (real or imagined) effects on wildlife. Evidence regarding the carcinogenicity of DDT is equivocal. The International Agency for Research on Cancer (IARC), part of the World Health Organization, includes DDT in Group 2B – possibly cancerous in humans. Animal studies have been cited in which orally-administered DDT induced liver tumors in mice and rats, and lymphomas and lung tumors and adenomas in

mice; however, studies in which DDT was administered orally to hamsters was negative, and inconclusive in dogs and monkeys (NIEHS). Other studies have provided no evidence for the carcinogenicity of DDT in mice and rats. According to the American Council on Science and Health (1998), serious flaws were uncovered in at least one of the studies, notably, that both case subjects and control subjects had developed a surprising number of tumors. Further investigation revealed that the food fed to both mice groups was moldy and contained aflatoxin, a known carcinogen. When the tests were repeated using non-contaminated food, neither group developed tumors. The Council also cites the conclusion in a 1978 National Cancer Institute report – after two years of testing on several different strains of cancer-prone mice and rats – that DDT was not carcinogenic.

DDT also has been widely blamed for causing thinning of eggshells and, subsequently, declines in bird populations, particularly of raptors. The American Council on Science and Health (1998) cites comparisons of the annual Audubon Christmas Bird Counts between 1941 (pre-DDT) and 1960, revealing that at least 26 different kinds of birds became more numerous during those decades, the period of greatest DDT usage. For example, only 197 bald eagles were documented in 1941; the number had increased to 891 in 1960. The Council also cites a carefully controlled feeding experiment in poultry which found no tremors, no mortality, no thinning of eggshells, and no interference with reproduction caused by levels of DDT that were as high as those reported to be present in most of the wild birds where catastrophic decreases in shell quality and reproduction have been claimed. In fact, thinning eggshells can be caused by a variety of factors, most notably calcium deficiency.

The primary routes of potential human exposure to DDT are inhalation, ingestion and dermal contact. It is believed that inhalation exposure to DDT will not result in significant absorption through the lung alveoli, but rather that it is probably trapped in mucous secretions and swallowed. If ingested, DDT is readily absorbed through the gastrointestinal tract, with increased absorption in the presence of fats. DDT is very slowly transformed in animals (including humans). DDT accumulates in fatty tissues and is found in higher concentrations in human milk than in cow milk or other foods (NIEHS). Levels of DDT or its metabolites in fatty tissues, such as fat cells or the brain, may occur at levels up to several hundred times that seen in the blood. Tissue levels probably increase with repeated exposure. Oral LD₅₀ values range from 113 to 1,800 mg/kg in rats; 500 to 750 mg/kg in dogs; and greater than 1,000 mg/kg in

sheep and goats. DDT is slightly to practically nontoxic in test animals via dermal exposure and is not readily absorbed through the skin unless it is in solution. Reported dermal LD₅₀ levels are 2,500 to 3,000 mg/kg in rats, 1,000 mg/kg in guinea pigs and 300 mg/kg in rabbits. The most significant source of exposure to individuals in the United States is occupational (EXTOXNET).

According to EXTOXNET, studies of humans occupationally exposed to DDT have shown that DDT may have the potential to cause genotoxic effects, but it does not appear to be strongly mutagenic. There is evidence that DDT causes reproductive and teratogenic effects in laboratory animals. Data from chronic exposure in animal studies indicate that DDT can affect the nervous and immune systems, liver and kidneys. Acute effects likely in humans due to low to moderate exposure may include nausea; diarrhea; increased liver enzyme activity; irritation of the eyes, nose or throat; disturbed gait; malaise; and excitability. At higher doses, tremors and convulsions are possible. EXTOXNET further states that while adults appear to tolerate moderate to high ingested doses of up to 280 mg/kg, a case of fatal poisoning was seen in a child who ingested one ounce of a 5 percent DDT:kerosene solution.

When evaluating the human health effects of DDT, perhaps consideration also should be given to the role DDT has played in the control of disease-causing insects. DDT controls many serious human diseases including bubonic plague, malaria, yellow fever, encephalitis and typhus (Fox, 1998). A case in point, spraying of DDT in Ceylon (now Sri Lanka) reduced the incidence of Malaria cases from 2.8 million in 1948 to 17 in 1963. After DDT usage was stopped in 1964, the number of malaria cases rose, reaching 2.5 million in 1969 (American Council on Science and Health, 1998). Currently, malaria is responsible for claiming up to 2.7 million lives a year; almost all fatalities are children and pregnant women (Environmental News Network, 1999).

Health advisory level: There is no MCL or HAL for DDT.

Treatment technologies: No information was available about treatment technologies to effectively remove DDT from contaminated water.

Dicamba

Common names: Common trade names for dicamba include Banex, Banvel, Dianat, Mediben, Brush Buster and Velsicol Compound R. Formulations of dicamba include Banvel 720, Brushmaster and Weedmaster premixes.

Chemical formula: The empirical chemical formula for dicamba is $C_8H_6Cl_2O_3$. Its composition is 2-methoxy-3,6-dichlorobenzoic acid (IUPAC).

Physical characteristics: Dicamba is crystalline at 25 degrees C. It has a solubility in water of 4,500 mg/l at that temperature. It is also soluble in ethanol, acetone and some ketones. The melting point of dicamba is 114 degrees to 116 degrees C. Retail formulations include liquids and granules.

Uses and occurrence: Dicamba is a herbicide used to control broadleaf weeds. In North Dakota in 1996, 4,653,300 agricultural acres were treated with dicamba (Zollinger et al., 1996). This was approximately 12 percent of the planted acres in the state.

Environmental fate: In studies, dicamba had a half-life of from one to six weeks in various soils; under field conditions, one to two weeks. Degradation rates decreased with decreasing temperature and soil moisture. Phytotoxic residues have persisted in aerobic soil for almost two years. Dicamba is highly mobile and exhibits considerable leaching effect. In addition, no appreciable loss occurs due to volatilization. Dicamba residues photodegrade in water to non-phytotoxic levels after approximately two weeks exposure to sunlight.

Health effects: Laboratory studies of rats, mice, rabbits and dogs indicate that dicamba is rapidly absorbed from the gastrointestinal tract. It does not appear to accumulate in mammalian tissues. In humans, exposed workers developed muscle cramps, dyspnea, vomiting, skin rashes, loss of voice or swelling of cervical glands. Acute oral LD_{50} values in small mammals have been reported to range from 757 to 1,414 mg/kg. Dicamba is classified in Group D: not classified. This category is used for substances with inadequate or no evidence of carcinogenicity in human and animal studies.

Health advisory level: There is no MCL for dicamba. A lifetime HAL has been set at 0.2 mg/l (200 μ g/l or 200 ppb).

Treatment technologies: Available data indicate granular-activated carbon (GAC) adsorption to be a possible removal technique for dicamba.

Diclofop-methyl

Common names: Common names for diclofop-methyl include Hoelon, Hoe-grass, Illoxan and One Shot (diclofop plus bromoxynil plus MCPA).

Chemical formula: The empirical chemical formula for diclofop-methyl is $C_{16}H_{14}Cl_2O_4$. Its composition is methyl 2-[4-(2,4-dichlorophenoxy)phenoxy]propanoate.

Physical properties: Diclofop-methyl is a colorless crystalline solid. It has a melting point of 39 degrees to 41 degrees C and is soluble in most organic solvents. Retail formulations include emulsifiable concentrates and oil in water emulsions.

Uses and occurrence: Diclofop-methyl is an herbicide used in the United States for control of grassy weeds in barley and wheat.

Environmental fate: Under aerobic conditions, diclofop-methyl hydrolyzes in a matter of days in the soil to 2-[4-(2',4'-dichlorophenoxy)phenoxy] propanoic acid, which in turn is degraded relatively quickly with a half-life of 10 days in sandy soils and about 30 days in sandy clay soils. Small amounts of 4-(2,4 dichlorophenoxy)phenol are also produced (Chemical Abstract Services, CAS # 51338273). Field studies of application rates up to 3.4 kg active ingredient per hectare (3.0 lb ai/acre) showed very low finite residues in soil (Chemical Abstract Services, CAS # 51338273). At harvest, small finite residues were present in the 0 to 7.5 cm (0 to 3 in.) soil level, and rare small residues were present above the 15 cm (6 in.) level. These studies indicate that diclofop-methyl does not leach downward or move laterally and dissipates quickly in soil.

Health effects: Diclofop-methyl is metabolized in mammals via hydroxylation. Chlorophenoxy compounds are absorbed across the gut wall, lung and skin. They are not significantly stored in

fat, and urinary excretion is the principal route of elimination. Elimination as a conjugate is within 96 hours (Chemical Abstract Services, CAS # 51338273). The acute oral LD50 for rats ranged between 563 to 693 mg/kg (in sesame oil), and the acute dermal LD50 for female rats was greater than 2,000 mg/kg (Handbook).

Dichlorprop

Common names: Trade names for dichlorprop include Kildip, Seritox 50, Patron and Riverdale DP-4.

Chemical formula: The empirical chemical formula for dichlorprop is $C_9H_8Cl_2O_3$. The structural formula is Propanoic acid, 2-(2,4-dichlorophenoxy).

Physical properties: Dichlorprop is a colorless to white or tan crystalline solid and is generally odorless but will occasionally have a phenolic odor. Dichlorprop decomposes when heated. Retail formulations include invert emulsions and soluble concentrates.

Uses and occurrence: Dichlorprop is used for brush control on aquatic weeds, rangeland and right-of-ways. It is more selective than 2,4-D and is used to control chickweed and cleavers in cereal grains, pastures and turf.

Environmental fate: Dichlorprop does not readily adsorb to soil particles; it is expected to leach. When in soil, dichlorprop can be persistent for more than 130 days. There is insufficient data to assess the importance of biodegradation in soil and water. When released to water, volatilization and bioconcentration in fish will not be important factors.

Health effects: Dichlorprop enters the body through dermal contact, inhalation and ingestion. Symptoms include diarrhea, headache, nausea and vomiting. There is no evidence that Dichlorprop is a carcinogen. The oral LD₅₀ is 825-1470 mg/l and the dermal LD₅₀ is >4000 mg/l.

Health advisory level: There currently is no MCL or HAL for Dichlorprop.

Treatment technologies: No information was available about the treatment technologies for

removing dichlorprop from drinking water.

Endosulfan I and Endosulfan Sulfate

Common names: Some of the common trade names for endosulfan are Amisulfan, Sulfanex, Ex-borer, Devisulfan, Sutene 35 EC, Thionate, Parrysulfan, Golden Lea, Thiodan, Dissulfan, Endozol and Thionil.

Chemical formula: The empirical chemical formula for Endosulfan I / Endosulfan sulfate is $C_9H_6Cl_6O_3S$. The structural formula is Hexachloro Hexahydro Methano-2,4,3-Benzo-Dioxathiepin-3-Oxide.

Physical properties: Endosulfan is a cream-to-brown-colored solid that may be in crystals or flakes and smells like turpentine. It has a melting point of 106 degrees C. Retail formulations include dusts, emulsifiable concentrates, granulars and wettable powders. Endosulfan sulfate is not commercially manufactured; it is found in the environment as a result of the use of Endosulfan.

Uses and occurrences: Endosulfan is an insecticide used to control insects on grains, tea, fruits, vegetables, tobacco and cotton. In the United States, endosulfan is used mainly on tobacco and fruit crops and also is used as wood preservative.

Environmental fate: Endosulfan does not dissolve easily in water and may remain in soil for several years before completely breaking down by biodegradation. Volatilization and leaching of endosulfan in soil are not significant because of its high soil adsorption. When released to water, endosulfan hydrolyzes.

Health effects: Endosulfan mainly affects the nervous system. Inhalation or ingestion of high levels of endosulfan results in convulsions, tremors, decreased respiration and death. Endosulfan has not been shown to be a carcinogen.

Health advisory level: There currently is no MCL or HAL for endosulfan.

Treatment technologies: No information was found about treatment technologies capable of removing endosulfan from drinking water.

Endrin and Endrin Ketone

Common names: Common trade names for endrin are Endrex and Hexadrin.

Chemical formula: The empirical chemical formula for endrin is $C_{12}H_8Cl_6O$. Its composition is 3,4,5,6,9,9-Hexachloro-1a,2,2a,3,6,6a,7,-7a-octahydro-2,7:3,6-dimethanonaphth[2,3-b]oxirene; 1,2,3-4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo,endo-1,4:5,8-dimethanonaphthalene.

Physical properties: Endrin is a colorless crystalline solid. The crystals decompose, or melt, at 245 degrees C. Endrin has a water solubility of 0.24 mg/l at 25 degrees C. Retail formulations include emulsifiable concentrates, wettable powders and dusts.

Uses and occurrence: Endrin is an insecticide once widely used in the United States. In 1979, the U.S. EPA canceled the use of endrin for a number of uses, and registration for new uses of endrin was denied. Endrin is presently registered only for the control of cutworms, grasshoppers and moles. The manufacture of endrin was discontinued in 1987 by Shell International Chemical Co., Ltd. Endrin ketone is a degradation product of endrin.

Environmental fate: Endrin is considered to be a persistent compound. Endrin biodegrades poorly and, once in the ground, endrin binds onto soils rapidly and migrates slowly. Endrin has the potential to bioaccumulate.

Health effects: Endrin is a central nervous system depressant and hepatotoxin. There is no antidote for endrin poisoning. Endrin is distributed in the fat, liver, brain and kidneys of mammals, both animal and human, and is metabolized rapidly. Endrin residues decline rapidly after cessation of exposure; however, both wild and domestic birds store endrin in various body tissues, especially fat. Exposure to endrin may cause sudden convulsions, headache, dizziness, sleepiness, weakness, nausea, vomiting, insomnia, agitation, mental confusion and loss of appetite. A number of deaths have been reported from both intentional and accidental ingestion.

The time periods from administration of the pesticide to death ranged from one to six months. Endrin ingestion with milk or alcohol appeared to increase toxicity, as death occurred within an hour or two, possibly due to more rapid absorption through the gastrointestinal tract. An oral LD₅₀ value of 7 to 15 mg/kg has been reported in rats. Endrin is classified in Group D: not classifiable. This category is used for substances with inadequate or no human and animal evidence of carcinogenicity.

Health advisory level: The MCL and lifetime HAL for endrin have been set at 0.002 mg/l (2 µg/l or 2 ppb).

Treatment technologies: Treatment technologies capable of removing endrin from drinking water include adsorption by activated carbon -- both granular and powdered -- air stripping, reverse osmosis and coagulation/filtration.

Malathion

Common names: Malathion is also known as carbophos, maldison and mercaptothion. Common trade names for malathion include Celthion, Cythion, Dielathion, El 4049, Emmaton, Exathios, Karbofos and Maltox.

Chemical formula: The empirical chemical formula for malathion is C₁₀H₁₉O₆PS₂. Its composition is diethyl (dimethoxythiophosphorylthio)succinate.

Physical properties: Malathion is a clear colorless liquid when pure; the technical grade is a deep brown or amber to yellow liquid. It has a skunk-like odor. It has a solubility in water of 130 mg/l and is miscible in most organic solvents. Malathion has a melting point of 2.9 degrees C and a boiling point of 156 degrees to 157 degrees C. Retail formulations include dusts, emulsifiable concentrates, oil solutions, powders and ultra low volume (ULV) concentrations.

Uses and occurrences: Malathion is a non-systemic, wide-spectrum organophosphate insecticide used to control insects that attack fruits, vegetables, cotton, lawns, ornamentals and stored products. It is also used in the control of mosquitoes, flies, household insects, animal parasites, and head and body lice in such non-agricultural uses as livestock, poultry, industrial, and home

and garden (Chemical Abstract Services, CAS # 121755). In 1996, malathion was applied to approximately 12,900 agricultural acres in North Dakota (Zollinger et al., 1998).

Environmental fate: Malathion binds moderately well to soil. It has a low persistence in soil with reported half-lives of one to 25 days. Malathion degrades rapidly, with degradation related to the degree of soil binding. Breakdown occurs through biodegradation, hydrolysis and photolysis (Chemical Abstract Services, CAS # 121755). Because it is soluble in water, it may pose a risk to groundwater or surface water under conditions that are not favorable to degradation.

Health effects: Malathion is rapidly and effectively absorbed by almost all routes including the skin, lungs, mucous membranes and the gastrointestinal tract. Elimination occurs very rapidly through the urine, feces and expired air, with a reported half-life of approximately eight hours in rats and two days in cows. Autopsy samples from one person who had ingested a large amount of malathion showed a substantial portion in the stomach and intestines, a small amount in fat tissue and no detectable levels in the liver. Symptoms of acute exposure to malathion are similar to those observed with other organophosphates or cholinesterase-inhibiting compounds, including tremors, nausea, abdominal cramps, numbness, tingling, uncoordination, headaches, dizziness, sweating, blurred vision, difficulty breathing and slow heartbeat. Very high doses may result in unconsciousness, incontinence, convulsions or death. The acute effects of malathion poisoning depend upon the purity of the product and the route of exposure. The amount of protein in the diet and gender are two additional factors which may influence the toxicity of malathion. In laboratory animal studies, toxicity increased in rats as the amount of protein in the diet decreased. In addition, malathion has been demonstrated to have different toxicities in male and female rats and in humans, probably due to differences in metabolism, storage and excretion between the sexes, with females being much more susceptible. Numerous incidents of malathion poisoning have been reported among pesticide workers and children because of accidental exposure. Animal studies have established a relationship between malathion and mutations, as well as developmental and reproductive effects. Malathion has been classified in category Group D: not classifiable. This group is used for agents for which there is inadequate or no human and animal evidence of carcinogenicity.

Health advisory level: The HAL for malathion is 0.2 mg/l (200 µg/l or 200 ppb).

Treatment technologies: No information was available about treatment technologies to remove malathion from drinking water.

Pentachlorophenol

Common names: Trade names for pentachlorophenol include PCP, sodium pentachlorophenoxide, Permatox 101, Permatox 181, Dowicide G-ST, Pentacon, Pentwar, GLAZD and Weedone.

Chemical formula: The empirical chemical formula for pentachlorophenol is C_6Cl_5OH . Its composition is pentachlorohydroxybenzene.

Physical properties: Pentachlorophenol is a synthetic, chlorinated organic herbicide. Pure pentachlorophenol is in the form of white- to buff-color crystals, beads or powder. The melting and freezing point of technical pentachlorophenol is 174 degrees C; for the anhydrous form, 191 degrees C. At room temperature, its solubility in water is 14 mg/l. Retail formulations include blocks, flakes, liquid concentrates or ready-to-use petroleum solutions. Pentachlorophenol, commonly called “penta” or PCP, as a formulated product is to be applied with a hydrocarbon diluent or as an emulsifiable solution. It is usually applied to wood products after dilution to a 5 percent solution with solvents such as mineral spirits, No. 2 fuel oil or kerosene.

Uses and occurrence: Pentachlorophenol was once one of the most widely used chemicals. PCP is a herbicide, antimicrobial agent, disinfectant, mossicide and defoliant. Its major uses are as a wood preservative for fungus decay and termite or Lyctus beetle attack and as a molluscicide for snail carriers of larval human-blood flukes causing schistosomiasis in Egypt. In 1985, PCP production was 35 million pounds. In the United States, PCP is a restricted-use pesticide as a wood preservative. Since 1987, wood preservatives and other pesticides containing pentachlorophenol are no longer available for home and garden use. Currently, the principal use for pentachlorophenol is as a commercial wood preservative for power line poles, cross arms and fence posts.

Environmental fate: PCP is very persistent in some soils, with half-lives of up to five years reported. PCP is rapidly degraded by sunlight: the half-life for photolysis of pentachlorophenol

in water is reported to be less than one hour. PCP is degraded by soil bacteria under some conditions; biodegradation may take several weeks or longer. Depending upon soil conditions, half the pentachlorophenol will be broken down by soil organisms in about two months. Migration occurs in neutral to alkaline soils. The occurrence of pentachlorophenol in ground and surface waters is rare.

Health effects: PCP is readily absorbed following oral, dermal or inhalation exposure. Once absorbed, PCP is distributed throughout the body, accumulating in the liver, kidneys, brain, spleen and fat. It apparently is metabolized readily, since a large portion of the administered dose is excreted unchanged by all species tested. The major route of elimination is in the urine, with feces as a minor route. Acute exposure in experimental mammals results in an initial rise in body temperature and respiration rate. The body temperature may increase to dangerous levels causing injury to various organs and tissues and even death. Respiration then becomes slower and dyspneic as coma develops. Death is characterized by cardiac and muscular collapse with terminal asphyxial convulsions. An immediate and pronounced rigor mortis often is noted. Oral LD₅₀ values ranging from 27 to more than 300 mg/kg have been reported, with no species being noticeably more susceptible than any other. Human exposure to PCP results in local irritation, systemic effects and, in a limited number of people, an allergic reaction. PCP poisoning is characterized by profuse sweating, often accompanied by fever, weight loss and gastrointestinal complaints. Liver and kidney involvement have been indicated in cases of fatal poisoning. PCP may affect reproduction in humans or cause harm to unborn babies. PCP is classified in Group B2: probable human carcinogen. This group is used for agents for which there is sufficient evidence of carcinogenicity from animal studies.

Health advisory level: The MCL for pentachlorophenol is 0.001 mg/l (1 µg/l or 1 ppb).

Treatment technologies: Treatment technologies which may be effective for PCP include adsorption with granular-activated carbon. The use of aeration also has been considered.

Picloram

Common names: The most common trade name for picloram is Tordon. Other trade names include Amdon, ACTP, Borolin and K-Pin.

Chemical formula: The empirical chemical formula for picloram is $C_6H_3Cl_3N_2O_2$. Its structural formula is 4-amino-3,5,6-trichloropicolinic acid.

Physical properties: At room temperature, picloram is a white powder. At 215 degrees C, picloram decomposes before it melts. It has a solubility of 430 mg/l at room temperature, with a slight chlorine-like odor. Retail formulations include water-soluble liquids and granules.

Uses and occurrence: Picloram is used as a broad-spectrum herbicide for the control of broadleafed and woody plants in rangelands, pastures, small grains and rights-of-way for power lines and roadways. In 1996, it was applied to approximately 280,600 acres in North Dakota (Zollinger et al., 1998).

Environmental fate: The main processes for dissipation of picloram in the environment are photodegradation and aerobic soil degradation. Photodegradation occurs rapidly in water, but is somewhat slower on a soil surface. Hydrolysis of picloram is very slow. Laboratory studies have shown that under aerobic soil conditions, the half-life of picloram is dependent upon the applied concentration and the temperature and moisture of the soil. Field tests have indicated that picloram's half-life varies from about one month to several months. Following normal agricultural, forestry or industrial applications, long-term accumulation of picloram in the soil generally does not occur. Under anaerobic conditions, picloram has been shown to be quite stable, with very little degradation.

Health effects: Picloram is readily absorbed by mammals through the gastrointestinal tract. It is not metabolized significantly in the body, however, and 90 percent to 95 percent passes through the body within about two days. The acute oral toxicity of picloram is low. Lethal doses have been estimated in a number of species, with LD_{50} values ranging from 2,000 to 4,000 mg/kg. In a study of mice, there was no indication of a carcinogenic response from dietary exposure. A rat study was negative for carcinogenic effects in males; however, females exhibited an increase in neoplastic nodules. Picloram has been included in Group D: not classified. This group is generally used for substances with inadequate human and animal evidence of carcinogenicity or for which no data is available.

Health advisory level: The MCL for picloram has been set at 0.5 mg/l (500 ug/l or 500 ppb).

Treatment technologies: No information was found about treatment technologies capable of effectively removing picloram from drinking water.

Simazine

Common names: Trade names for simazine include Aquazine, Caliber, Cekusan, Cekusima, Framed, Gesatop, Primatol S, Princep, Simanex, Sim-Trol, Tanzine and Totazine (EXTOXNET).

Chemical formula: The empirical chemical formula for simazine is $C_7H_{12}ClN_5$. Its composition is 6-chloro-N,N'-diethyl-1,3,5-triazine-2,4-diamine.

Physical properties: Simazine is a pre-emergent selective herbicide. Simazine is a white or colorless crystalline solid at room temperature. It has a melting point of 225 degrees to 227 degrees C. It is soluble in solvents such as methanol, chloroform, diethyl ether and pentane; however, it has a low solubility in water, 3.5 mg/l at room temperature. Retail formulations include wettable powders, water-dispersible granules, liquids and granules.

Uses and occurrence: Simazine is a triazine, a group of chemically similar herbicides that also includes atrazine, cyanazine and propazine. Triazines primarily are used to control broadleaf weeds. Simazine is used to control broadleaf weeds and annual grasses in field crops, berries, nuts, vegetables, ornamentals, orchards, vineyards and turfgrass. Prior to 1992, simazine also was used to control submerged weeds and algae in large aquariums, farm ponds, fish hatcheries, swimming pools, ornamental ponds and cooling towers (EXTOXNET). There were no agricultural acres reported with simazine application in 1996 (Zollinger et al., 1998).

Environmental fate: Simazine is moderately persistent, with reported half-lives in soil of 28 to 149 days (EXTOXNET). Simazine residues may persist for up to three years in soil under aquatic field conditions. Simazine binds moderately to poorly to soils, but does adsorb to clays and mucks; adsorption increases as acidity, organic matter and clay content increase. The low water solubility of simazine makes it less mobile, thus limiting its leaching potential. However, mobility may vary from slight to very mobile, depending upon soil type. Breakdown of simazine can occur through biodegradation, chemical hydrolysis, photolysis and decomposition by ultraviolet radiation; however, the rate of degradation is generally slow and dependent upon

several factors, including soil pH, soil moisture and temperature. The long soil persistence of simazine creates a problem of soil carry over, which can damage succeeding crops. Simazine is not expected to bioconcentrate in aquatic organisms.

Health effects: The most probable human exposure is occupational, through inhalation or dermal contact, in the production of simazine or its use as a herbicide. Simazine is slightly to practically nontoxic. The oral LD₅₀ in mice and rats is greater than 5,000 mg/kg; however, sheep and cattle are especially susceptible to simazine poisoning -- a single oral dose of 500 mg/kg was fatal to sheep. When ingested, 60 percent to 70 percent of the chemical is absorbed, with approximately 5 percent to 10 percent distributed to the tissues. The remainder is eliminated in the urine within 24 hours. The triazine herbicides disturb thiamin and riboflavin functions. Symptoms include tremors, gut pain, cyanosis, convulsions, difficulty in walking, paralysis, slowed respiration, miosis, diarrhea and impaired adrenal function. Chronic effects can include damage to the testes, kidneys, liver and thyroid; disturbances in sperm production; and gene mutations. Simazine has been classified in Group C: possible human carcinogen. This category includes agents for which there is limited evidence of carcinogenicity from animal studies and inadequate or no data in humans.

Health advisory level: The MCL for simazine is 0.004 mg/l (4 µg/l or 4 ppb).

Treatment technologies: Treatment technologies that will remove simazine from water include activated carbon adsorption; ion exchange; and chlorine, chlorine dioxide, ozone, hydrogen peroxide and potassium permanganate oxidation.

2,4,5-T

Common names: Trade names for 2,4,5-T are Weedone, Tributon, Tormona, T-Nox, Brushkiller and Esterone.

Chemical formula: The empirical formula for 2,4,5-T is C₈H₅Cl₃O₃. Its structural formula is 2,4,5-trichlorophenoxyacetic acid.

Physical properties: 2,4,5-T is an odorless, white or tan solid. It is soluble in water, has a melting

point of 153 degrees C and decomposes before it reaches a boiling point.

Uses and occurrences: The use of 2,4,5-T has been canceled in the United States since 1985. Prior to cancellation, 2,4,5-T was used as a herbicide in recreation areas, lumber yards, vacant lots and on food crops for humans. It also was used as a growth regulator to increase the size of citrus fruits and reduce excessive drop of deciduous fruit.

Environmental fate: 2,4,5-T will biodegrade in soil and its mobility will vary depending upon the type of soil, from highly mobile in sandy soils to slightly mobile in humus-rich, fine-textured soils. The persistence of 2,4,5-T in soils varies from 14 to 300 days, depending upon climatic conditions and soil microorganisms.

Health effects: Short-term effects from exposure to 2,4,5-T produce symptoms such as headache, nausea, fatigue and muscular aches. Birth defects were noticed from long-term exposure to 2,4,5-T. Some of the defects include increased chance of babies born with facial clefts and club foot. In a study, five male volunteers ingested 5mg/kg 2,4,5-T. Essentially all the 2,4,5-T was excreted unchanged via the urine. The EPA (1986) has classified 2,4,5-T in the group D category. This category is for agents with inadequate animal evidence of carcinogenicity.

Health advisory level: The HAL for 2,4,5-T is 0.07 mg/l (70.0 μ g/l or 70 ppb).

Treatment technologies: No information was available about treatment technologies to remove 2,4,5-T from drinking water.

Trifluralin

Common names: The most common trade names for trifluralin are Treflan, Agreflan and Crisalin.

Chemical formula: Trifluralin's empirical chemical formula is $C_{13}H_{16}F_3N_3O_4$. Its composition is alpha, alpha, alpha-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine (IUPAC).

Physical characteristics: At normal temperatures, trifluralin is an orange crystalline solid. It is

practically insoluble in water (0.3 mg/l at 20°C), but it is readily soluble in organic solvents such as xylene, acetone and aromatic naphthas. Retail formulations include granules, emulsifiable concentrates and liquids.

Uses and occurrence: Trifluralin is a selective pre-emergent herbicide for control of annual grasses and broadleafed weeds. It is applied to small grains, beans, vegetables, fruits, flowers, golf courses, and domestic and industrial sites. Zollinger et al. (1998) report that in North Dakota in 1996, trifluralin -- alone, or in formulation with other chemicals -- was applied to approximately 2,030,800 acres, or approximately 6 percent of the total planted acres in North Dakota.

Environmental fate: Trifluralin is relatively immobile in soils due to its high soil partition coefficients. Under aerobic conditions, trifluralin has a soil half-life of approximately two to four months. Trifluralin appears to degrade even faster under anaerobic conditions, with one study showing less than 1 percent left in the soil after 20 days.

Health effects: Trifluralin is not readily absorbed from the gastrointestinal tract of mammals, and the fraction that is absorbed is completely metabolized. Acute oral toxicity of trifluralin is low in mammals, with LD₅₀ values ranging from 2 grams per kilogram (g/kg) to 10 g/kg. Trifluralin exposure has resulted in dermal and ocular irritation in humans. Other reported symptoms include respiratory involvement, abdominal cramps, nausea, diarrhea, headache, lethargy and paresthesia following dermal or inhalation exposure. It is highly toxic to fish, with a LC₅₀ value for rainbow trout of 12 to 40 µg/l (12 to 40 ppb). Trifluralin has been classified in Group C: possible human carcinogen. This category is used for substances that show limited evidence of carcinogenicity in animals and inadequate evidence in humans.

Health advisory level: The lifetime HAL for trifluralin has been calculated to be 0.0021 mg/l (2.1 µg/l or 2.1 ppb).

Treatment technologies: Available data indicate that reverse osmosis, granular- or powdered-activated carbon adsorption, and possibly air stripping will remove trifluralin from drinking water.

Nitrate and Nitrite

Chemical formula: The empirical chemical formula for nitrate is NO_3 or NO_2 .

Uses and occurrence: The major use of nitrate and nitrite is in inorganic fertilizers. They also may be derived from septic systems, feedlots or areas with heavy manure loading, or from the decomposition of other organic materials. Nitrates and nitrites also are used extensively in the manufacture of explosives and in the curing of meats. The North Dakota Agricultural Statistics Service (1998) reported that 1,332,778 gross tons of fertilizer were applied in North Dakota in 1997, with 594,686 tons of that being nitrogen nutrient content. By comparison, 962,738 gross tons of fertilizer were applied in 1999, with 386,965 tons of that being nitrogen nutrient content (North Dakota Agricultural Statistics Service, 2000).

Environmental fate: Nitrates and nitrites in groundwater have been shown to degrade or dissipate with depth in an aquifer. The rates vary widely, depending upon temperature and other factors. The exact processes are not completely understood. Because nitrite is easily oxidized to form nitrate, nitrate predominates in groundwater. Nitrate and nitrite ions are very mobile in soil and groundwater.

Health effects: Ingestion of nitrates and nitrites has resulted in a condition known as methemoglobinemia, which is sometimes referred to as "blue baby syndrome." Methemoglobinemia is caused by the reaction of nitrite (not nitrate) with red blood cells to form methemoglobin, which does not carry oxygen as normal hemoglobin does. This may result in anoxemia and cyanosis, and, in severe cases, may be fatal.

While nitrate is readily excreted by the kidneys and is not directly metabolized in the human body, it is metabolized by bacteria in humans. In adults, high acidity levels in the gastrointestinal tract limit the number of nitrate-reducing bacteria; however, the lower gastrointestinal acidity levels in infants allow greater numbers of these bacteria to survive. These bacteria convert nitrate into nitrite, which is absorbed by the bloodstream. The oxygen starvation condition resulting from high concentrations of methemoglobin in the bloodstream will cause an infant's skin to have a bluish color. This is the reason methemoglobinemia is sometimes called blue baby syndrome. As an infant grows older, numbers of nitrate-reducing bacteria decrease, as do

chances for developing methemoglobinemia.

Health advisory level: Nitrate is toxic because it can be converted to nitrite and the total toxicity of the two is additive. Therefore, nitrate and nitrite cannot be considered independently. The MCL for nitrite in drinking water is 1.0 mg/l as nitrogen. The MCL for nitrate is 10.0 mg/l (N), as is the MCL for total nitrate plus nitrite (N). These levels have been set to protect infants. Adults can safely ingest greater concentrations than this, and ruminant animals (cattle, sheep, etc.) can normally consume concentrations up to 100 mg/l.

Treatment technologies: Methods to remove nitrate from drinking water include distillation and reverse osmosis.

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APPENDIX F

List of Abbreviations and Acronyms

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CAS	Chemical Abstracts Service
DC	Division of Chemistry
DRASTIC	d epth to groundwater, r echarge, a quifer media, s oil media, t opography, i mpact of the vadose zone and hydraulic c onductivity
EERC	Environmental Energy and Research Center
ENN	Environmental News Network
EPA	Environmental Protection Agency
EXTOXNET	Extension Toxicology Network
HAL	health advisory level
IARC	International Agency for Research on Cancer
IUPAC	International Union of Pure and Applied Chemistry
MCL	maximum contaminant level
$\mu\text{g/l}$	micrograms per liter, equivalent to ppb or 0.001 mg/l (liquid volume measurement)
$\mu\text{mhos/cm}$	micromhos per centimeter
mg/l	milligrams per liter, equivalent to ppm or 1000 $\mu\text{g/l}$ (liquid volume measurement)
N	(as) nitrogen
NIEHS	National Institute of Environmental Health Sciences

NDDoH	North Dakota Department of Health
NO ₃	nitrate plus nitrite
PAL	Prevention Action Level
ppb	parts per billion
ppm	parts per million
PSMP	Pesticide State Management Plan
QA/QC	Quality Assurance/Quality Control